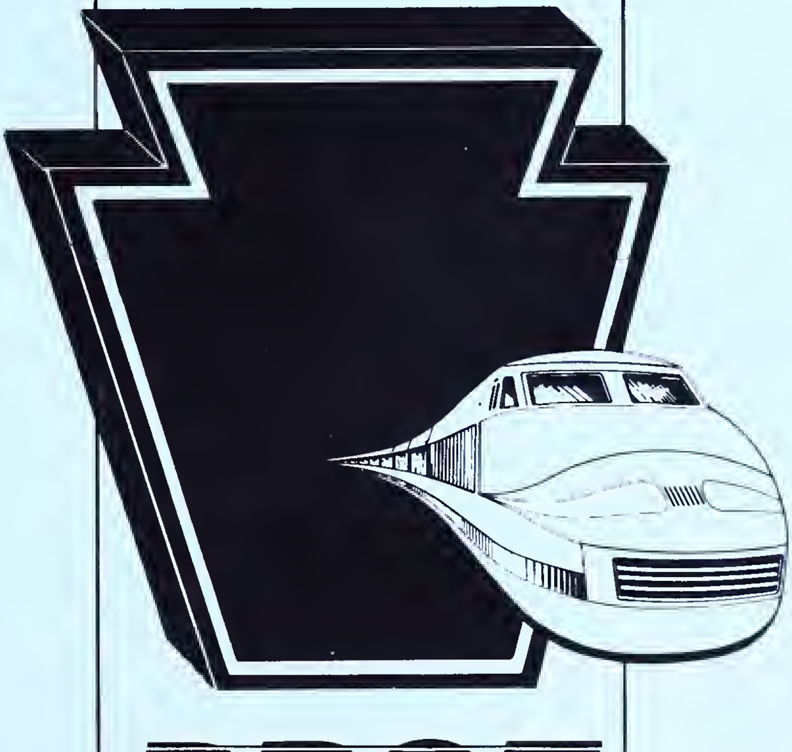
PENNSYLVANIA HIGH SPEED RAIL FEASIBILITY STUDY

MARKET DEMAND

PREPARED FOR:

PENNSYLVANIA
HIGH SPEED
INTERCITY
RAIL PASSENGER
COMMISSION



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JULY 1986

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Pennsylvania High Speed
Intercity Rail Passenger
Pennsylvania High Speed Rail
Feasibility Study

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The preparation of this report, dated July 1986, has been financed in part through a grant from the U.S. Department of Transportation, Federal Railroad Administration, to the Pennsylvania High Speed Intercity Rail Passenger Commission.

EXECUTIVE SUMMARY

GENERAL

By the year 2000, between 5.5 million and 8.8 million people annually could be riding a world-class, state-of-the-art high-speed railroad across Pennsylvania. Such a system, on which hourly trains would cruise at top speeds of 180 to 250 mph, would shrink travel time between Philadelphia and Pittsburgh to between 2 and 2½ hours, compressing the breadth of Pennsylvania geography to the range at which most travel in the state now takes place.

SIGNIFICANCE

Revenue and ridership forecasts for high speed rail projects are widely recognized as being among the most critical elements in determining the feasibility of high speed rail programs. The quality and comprehensiveness of these forecasts must be sufficient to generate public support for implementation of high speed rail systems and to provide the information necessary to obtain funding for implementation.

The Pennsylvania high speed rail travel analysis closely follows the Standard Guidelines for Revenue and Ridership Forecasting developed by the High Speed Rail Association (HSRA) Demand Forecasting Committee. By clearly stating all the assumptions that have been made in this study, and by showing forecasts and sensitivity tests that are based on an evaluation of all aspects of travel demand analysis, the study aims to credibly answer questions that the public, reviewing agencies and investors might raise.

The HSRA's Standard Guidelines were developed because of the tentative quality, lack of disclosure of methods and uncertain comprehensiveness of some early high speed rail travel analyses in proposed corridors elsewhere in the United States. These early studies had led to confusion and even disbelief among the public, the investment community and government officials. Though these efforts were the fruit of good intentions and enthusiasm, the Pennsylvania study must avoid repeating this experience, and therefore closely follows the HSRA guidelines.

APPROACH/ PROCEDURES

The demand analysis examines current decisionmaking patterns for personal and business travel in the Pennsylvania corridor and overlays that with a prospective improvement in transportation. It then predicts how travelers will react to that change, even though today's travelers might not have experienced it. That simplistic description, however, masks the depth of detail in which information was gathered, and the extent of sophistication reflected in the calculation of the forecast. The analysis was conducted in several steps:

First, several mathematical equations used in travel demand forecasting were evaluated and two--"trip generation/

distribution" and "multi-nomial mode choice" equations were selected. Written as a computer program, each equation is known as a model, or computer model.

DATA COLLECTION/ ANALYSIS

Second, an objective origin-destination survey was conducted in May and June 1985, with 25,538 questionnaires randomly distributed to Amtrak, turnpike and airline travelers in the Philadelphia-Harrisburg-Pittsburgh corridor. Nearly 8,900 forms were returned, a response rate of better than 30 percent. These surveys were intended to gauge who is traveling in the corridor, how often and why; what time of day they are making their trip and how much time it took them to get to the airport, train station or toll booth; where they are coming from and going to; who is paying for their travel, and other factors. Because the actual number of trips made each day on each of the modes was known, the responses could be mathematically expanded to represent total travel volume in the Pennsylvania corridor.

Third, two sets of market research surveys were conducted in August 1985. In these, more than 200 randomly chosen volunteers were tested in a focus-group setting to learn the subjective criteria on which they decide how to travel, and how they might respond to the attributes of a high speed rail option. The volunteers were tested to determine how much they valued such important but difficult-to-measure factors as comfort, convenience, reliability, perceived safety, security and amenities.

For each of the several thousand trips from the rail-turnpike-air survey, detailed tripmaking criteria were entered into the computer. Not only were the factual answers from the forms important, but each also was categorized by its traveler's point of origin and destination, and weighted with socioeconomic data specific to 121 separate origin and destination zones. These factors included population, area, average per capita income, number of families, average family income, employment density, size of labor force, number of hotel/motel rooms and college enrollment. At the same time, a hypothetical high speed rail system was constructed in computer language, with vehicle top speeds, acceleration and braking rates, and alignment characteristics, including grades and curves, being accounted for. For both a classic steel-wheel high speed rail system and an advanced magnetic levitation (or maglev) system, this information was fed through a computer "train performance model" to determine station-to-station trip times and overall running times.

CALIBRATION AND TESTING

Next, the trip characteristics from the rail-turnpike-air survey and other background information were run through the computer model to generate a statistical snapshot of the existing, or 1985, travel patterns in the corridor. The computer models then were "calibrated" by trip purpose (commuter, business, tourist, school and other) and distance. Calibration consists of running the computer model with trial numbers in some key parts of the equation and seeing how closely the results replicate known, or "observed" travel patterns. The formula was adjusted to match existing conditions; for example, its results must display similar zone-to-zone travel patterns, and the same percentage of short trips to long trips, as are actually known to occur. Calibration has but one purpose: To make the computer model mirror current travel habits as closely as possible, so that it will accurately forecast future trends when these variables are changed to represent what is expected for the years 2000 or 2010.

Sensitivity tests then were conducted on the resultant computer equations to determine the influence of travel time, travel costs, frequency of service and access and egress time on travel demand estimates.

Data then were loaded into the equation to represent population, employment, and other socioeconomic data forecasted for each of the 121 travel zones for the year 2000. In addition, the estimated total travel demand was factored into the equation, as were the traveler preferences derived from the August 1985 market surveys. These were used to determine modal split, or what percentage of travelers is likely to prefer the attributes of each mode--auto, air, bus or high speed rail--that could exist in the corridor in the year 2000. The result is a demand forecast that delineates, by mode, by origin and by destination, what travel patterns in Pennsylvania are likely to be in the year 2000. Among the findings is that a reduction in travel time such as that brought on by high speed rail generates instances of travel where none previously existed because it was too long or inconvenient. The forecast includes a range of the uncertainties involved, the effect that high speed rail would have on other travel in the corridor, and the effect high speed rail could have on the number of trips for various trip purposes.

Further tests of "reasonableness" were run to determine the possible effect on ridership that might result from competitive actions by other carriers, the influence of real estate development near stations, the effect of highway construction and the effect of economic activity that would be generated by various high speed rail technologies. Results of the market demand analysis were compared with the experience of other high speed rail systems operating throughout the world.

FORECASTS

In the year 2000, it is estimated that a 180 mph steel-wheel high speed rail market in Pennsylvania would range from approximately 5.5 million to nearly 7.8 million passengers, and that this ridership would rise to between 6.7 million and 14.3 million passengers by the year 2010. The estimates for a 250 mph maglev system are slightly higher and range from 6.2 million to 8.8 million passengers in the year 2000 to between 7.7 million and 16.2 million passengers by the year 2010.

Summary of Annual Market Demand Estimates
(Millions)

High Speed Rail Estimates

Description	Estimate		
	Low	Most Probable	High
Base Demand	5.376	6.248	6.873
Atlantic City*	.084	.084	.120
Mid-State*	0	.237	.788
Year 2000 Total	5.460	6.569	7.781
Year 2010 Total	6.720	10.530	14.300

Maglev Estimates

Description	Estimate		
	Low	Most Probable	High
Base Demand	6.168	7.168	7.885
Atlantic City*	.086	.086	.123
Mid-State*	0	.241	.805
Year 2000 Total	6.254	7.495	8.813
Year 2010 Total	7.700	11.300	16.200

*See pages 62-64.

TESTS OF REASONABLENESS

To test the reasonableness of these projections, some of the major characteristics of high speed rail services throughout the world were evaluated, including population density, maximum speed, corridor length, frequency of service, and ridership. From this analysis, a simple linear regression equation was developed to provide estimates of the "probable" and "possible" ranges of high speed rail passengers within the high speed rail corridor in Pennsylvania. This analysis indicates that either of the high speed rail alternatives being evaluated in Pennsylvania would achieve about half the ridership experienced today in the Paris-Lyon TGV corridor, and possibly attain the level of ridership observed in the Hanover-Munich corridor. It is also estimated that within 10 years of start-up, Pennsylvania high speed rail ridership could approach that now observed in the Paris-Lyon TGV corridor. As a result of this analysis, all of the market demand estimates appear to be well within a reasonable value and even the high-range estimates are not considered unattainable.

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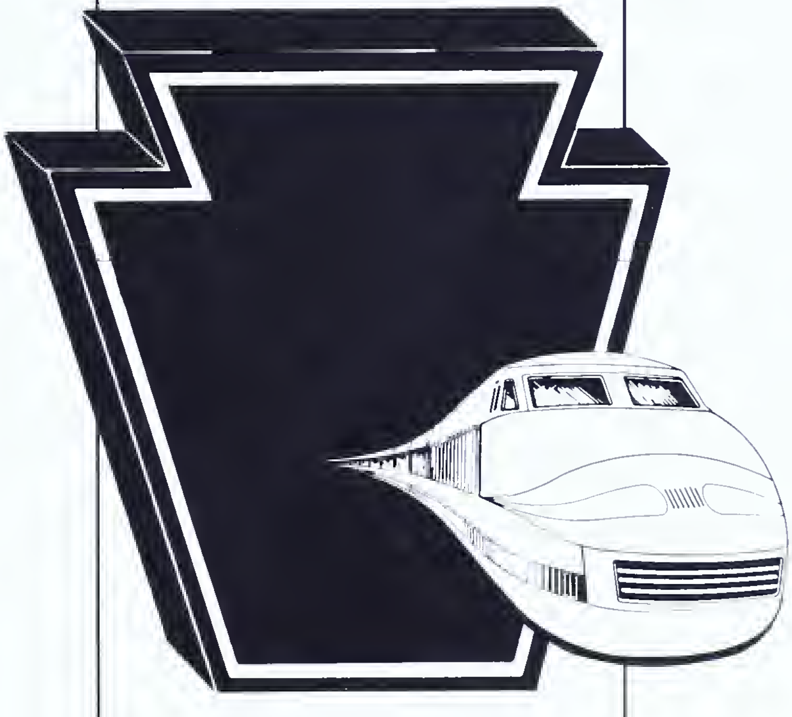

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JULY 1986

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TABLE OF CONTENTS

Page No.

INTRODUCTION 1

DEVELOP APPROACH 4
  Evaluate Models 5
  Conduct Surveys 7
  Obtain Expert Opinion 8

DATA COLLECTION 9
  Socioeconomic Data 9
  Vehicle Characteristics 12
  Alignments and Train Performance Modeling 13
  Physical Characteristics 13
  Existing Travel Patterns 15
  Origin and Destination Survey Results 17
  Seasonal and Hourly Variations 24

FORECAST DETAIL 24

CALIBRATION 35

SENSITIVITY TESTING 41

PRESENTATION OF FORECASTS 49

TESTS OF REASONABLENESS 69

INTRODUCTION

The general objectives of the Travel Demand Analysis are to provide reasonable estimates of:

- Total rail, air, bus, and automobile ridership, to better determine the importance of rail speed on the ridership of all modes.
- Revenues from rail fares so that they can be optimized. (That is, to obtain the highest net revenues or differences between revenues and operating cost.)
- Station-by-station boardings to help determine the size of stations, including parking lots, and numbers and types of operating personnel.
- Peak and off-peak rail ridership, to develop train schedules and vehicle/train requirements.
- Market demand by market segments so that rail operations can be designed to cater to each market and total revenues can be optimized.

The enclosed report provides a realistic study of high speed rail and provides an evaluation of the different market segments that are using the existing transportation systems, including the rail system, in Pennsylvania. These rail markets are:

- Commuter trips
- Business trips
- Tourist trips
- School trips
- Other trips

To gain understanding of these market segments, origin and destination surveys were conducted on Amtrak trains, in airports, and on the Pennsylvania Turnpike. Responses to these surveys suggested that there are important differences in travel behavior among the segments. A "business" trip is defined as a trip made once or twice a week to conduct some sort of business activity. Business trip costs are generally paid by an employer, who has a tendency to view the full costs of all modes in comparison to the time and cost of an employee's travel. "Commuter" trips are defined as travel made three or more times per week. Some of these may actually be "business" trips while others are home-to-work commuter trips. A commuter tends to view the fare as an out-of-pocket cost, unless it is paid by his employer. (Note: The survey indicated that more than 33% of these trips are now supported by employers; this percentage could be higher and depends on the schedule reliability and value of travel time to both employee and employer.) In a similar manner, tourist trips have characteristics different from either business and commuter trips or personal business and social trips. The cost of tourist travel is generally much more important to the potential rail user than travel time. The survey also indicated some important differences between the school trip and "other" types of trips, which have different travel characteristics.

During this analysis, it was assumed that public and private support will be necessary to actually implement a major transportation improvement, such as a high speed rail system, if found to be economically/financially feasible. It was assumed that this support will be obtained only by maximizing rail revenues and attracting more rail riders.

To satisfy these requirements, the work plan in Figure 1 illustrates how the Pennsylvania High Speed Rail Study ridership estimation was developed. This work plan includes:

- Developing an approach to provide an evaluation of existing methods and mathematical models for estimating travel demand; conducting surveys to establish the origins and destinations of today's travelers in Pennsylvania; and conducting market research surveys to better understand people's perceptions of different travel modes. Expert opinions were also obtained to establish operational concepts for implementing and operating a high speed rail system.

- Initiating a major data collection effort to establish current socioeconomic conditions and project future conditions that would exist at the time a high speed rail system was implemented. Also established were vehicle characteristics, alignments and physical characteristics associated with the Pennsylvania system, existing travel patterns, and seasonal variations that should be considered in implementing high speed rail.

- Conducting surveys to provide an understanding of the market including trip purpose, trip characteristics, and other variables that required evaluation during the analysis.

- Designing computer models and after the models were developed, data were collected, and an understanding of the different market segments gained, a computer program was calibrated by trip purpose and by trip distance.

- Conducting a sensitivity test to better understand the impact of variations in travel time, travel cost, frequency of service, and access and egress travel times.

The travel demand forecasts include our understanding of the uncertainties involved in making travel demand analyses and the impact of high speed rail on all travel in the corridor. Tests of reasonableness also were conducted to better understand:

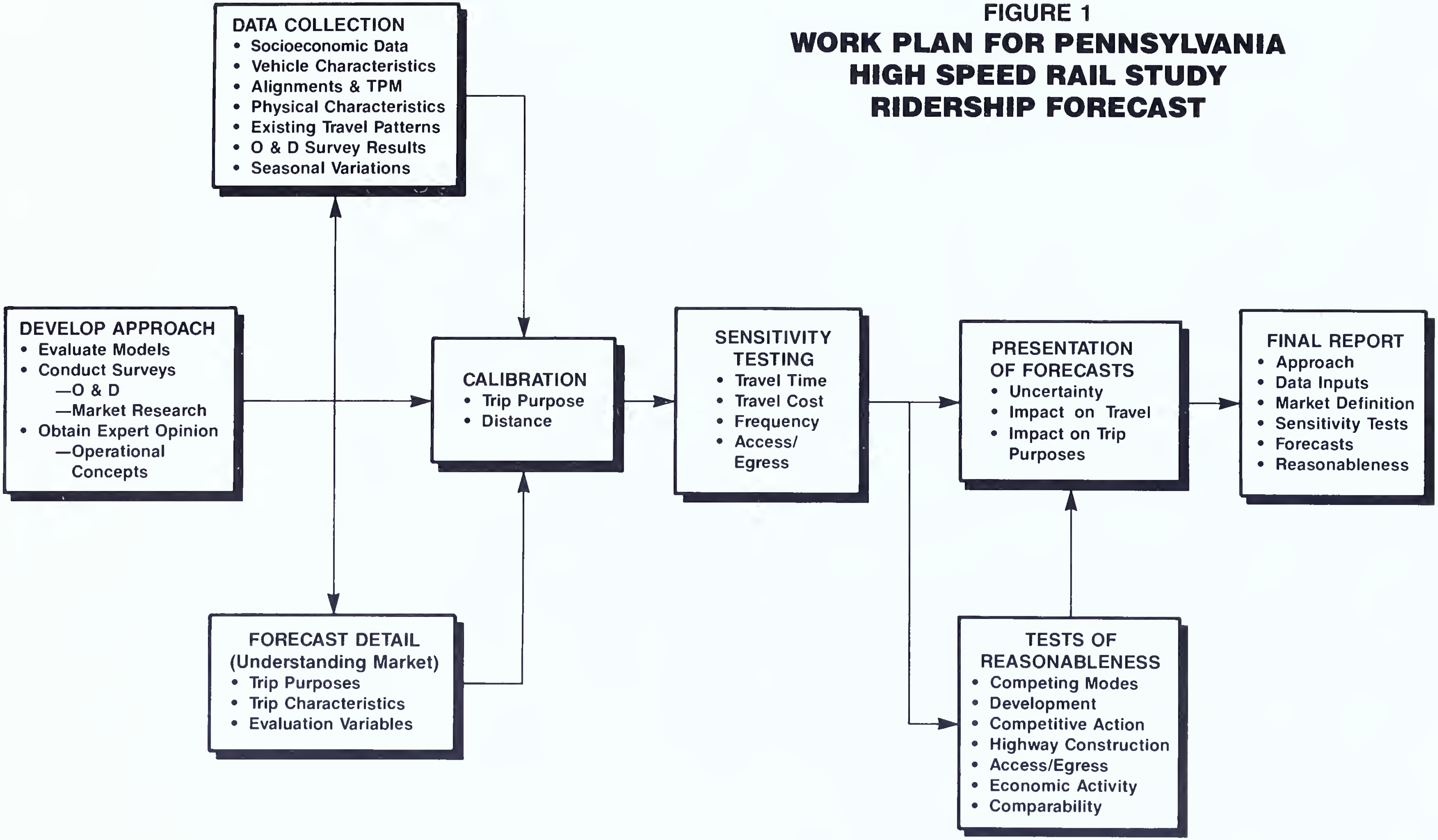
- The effect of a high speed rail system on other modes.

- The development that should occur because of the implementation of a high speed rail system.

- The effects that competitive action could take to reduce the high speed rail market.

- The impact that the high speed rail system would have on highway construction.

FIGURE 1
WORK PLAN FOR PENNSYLVANIA HIGH SPEED RAIL STUDY RIDERSHIP FORECAST



- The possible influence of increased economic activity and a comparison of the Pennsylvania rail travel demand estimates with rail ridership on existing high speed rail systems throughout the world.

All of these aspects were considered in this study and are explained in the following sections of this report.

DEVELOP APPROACH

In developing an approach to demand forecasting, it was necessary to define the requirements for this type of analysis and the mathematical model that would be used to forecast ridership. The requirements are:

- The model must permit analysis of market segments that have different travel characteristics and requirements. There is ample evidence to suggest that there are important differences in travel behavior that are related to travel cost, travel time including the period of travel, frequency of service and on-time reliability, and access and egress time and cost. In addition, the model must evaluate other factors of travel that are difficult to measure and associated more with perceptions of alternative modes of travel than to actual differences. These perceptions include safety, security, comfort, convenience, on-time reliability in all weather conditions, and the amenities associated with each mode of travel.

- The model must provide an understanding of the impact of increased train speed on all modes of travel so that future requirements for all types of transportation facilities and improvements can be established. In particular, as rail speed increases, we must be able to estimate the change in requirements for additional highway construction, airport facilities and reductions in airport congestion, and the influence on private transportation systems such as intercity bus companies and local feeder bus services.

- The model should provide an understanding of "induced demand", or incentives for making longer-distance trips that are not now made. This "induced demand" for travel may be created by changes in land use and the concentration of development around rail stations, but it also could be related to diversions from travel in other corridors and areas due to the travel time savings associated with high speed rail.

- The model should assist in determining the size of the high speed rail stations and auto, bus, and other interface requirements. Of particular importance is the determination of parking lot requirements since inadequate parking capacity has proven to be a deterrent to the use of some rail systems.

- The model must not make excessive demands for data or be too complex to permit an understanding of the more important travel characteristics that are necessary to develop operational concepts that are important in establishing and operating the high speed rail service.

Using these guidelines, previously developed mathematical models were evaluated and two were selected for estimating high speed rail market demand. Surveys were then designed to provide for the calibration of the mathematical models and provide an understanding of the travel characteristics of potential high speed rail travelers in the Pennsylvania corridor. These aspects of this study are discussed in the following sections.

Evaluate Models

Models that have previously been used to estimate high speed rail travel are called "post-distribution methods"; they use at least three steps in the standard transportation planning process: trip generation; trip distribution; and modal split. These modeling methods are designed to provide more complete information on total travel conditions and are sensitive to changes in service characteristics; however, they may require relatively large quantities of data and are typically more complex than other procedures, involving considerable data processing and manipulation.

A widely accepted method of estimating total travel demand is to relate this total demand to the population and employment in various zones and to trip time between zones. A mathematical procedure is then used to calibrate the constants and establish trip-making rates over time. After the constants have been calibrated, they can then be used to project interzonal trips for a total market. However, total trip-making may increase over time due to the following:

- Expansion of industries and occupations with high travel potential, such as service industries and white-collar occupations.
- Increased affluence and more leisure, which stimulate pleasure travel and tourism.
- Changing age distributions, especially older age distributions, which mean more persons in high-travel-potential age groups.
- Fewer dependents, which allows more time and disposable income for travel.
- The rising relative affluence of other countries, which will increase tourism to the United States, creating new demands on intercity transportation systems.

All types of mathematical models were evaluated, including "aggregate models" and "disaggregate intercity travel models". These models are all discussed in the report entitled "Review of Intercity Passenger Travel Demand Modeling: Mid 60's to the Mid 80's by Frank S. Coppleman, et al, September 1984".

After a careful review of the characteristics of the preceding mathematical models, a trip generation/distribution model and multi-nomial mode choice model were selected for this analysis.

The trip generation/distribution model was developed from analysis of extensive surveys of east-west travelers in Pennsylvania. This new data base includes the number of trips by origin and destination pair, by trip purpose, and by mode. Characteristics of travelers such as their age, income and family status were also available from this survey. Socioeconomic data describing the population, employment, geographic area and average family income were gathered for each of the zones in the study area. These data were aggregated on the basis of a finer-grained zonal system than that previously used, which greatly improved the capability to establish trip generation and distribution characteristics. The trip generation/distribution models were determined to be slightly different for each type of trip. For example, the numbers of commuter trips and business trips were estimated by determining the interrelationships among the number of workers available at the trip origin, the per capita income at the origin, the employment at the destination, and travel time and travel cost from origin to destination. The mathematical model for tourist trips considered the interrelationships among population and per capita income at the origins, number of hotel/motel rooms at the destinations and travel time and travel cost from origin to destination. The trip generation/distribution computer model for home-based school trips was estimated from an evaluation of the interrelationships among numbers of families and family income at the origins, college enrollment at the destinations and travel time and travel cost from origin to destination. The trip generation/distribution computer model for home-based "other" trips was estimated from an evaluation of the interrelationships among the population and family income at origins, employment at the destinations, and travel time and travel cost from origin to destination. These computer models established the total travel generated among all origins and destinations in the study area. The selected mathematical model avoids the problem of calibrating trip production, trip attraction and trip distribution separately. It provides a built-in mechanism for estimating the effects of change in travel times and travel costs on travel demand, thus providing some insight into the nature of "induced" travel. The reason for this capability is that the weighted average travel time and travel cost are changed due to the introduction of a new high speed mode, or major improvements to an existing mode, thus changing the estimated total number of trips within the study area. The mathematical expression can also be calibrated directly using a multiple linear regression technique on the logarithmic transformation of the equations, thus avoiding the trial-and-error calibration procedures that are inherent in many other computer models.

The modal split model selected is based on the economic theory of consumer behavior that is embodied in the logit statistical model. Mode choice is related to the interrelationships among travel cost, travel time, frequency of service, and access time for all travel modes (rail, bus, auto, and air). The mode choice model was calibrated with data from an evaluation of the 1980 Journey-to-Work data obtained from the U.S. Census and from the results of a reasonably comprehensive May 1985 survey of travelers in Pennsylvania. This traditional modeling process has proven to be a valuable tool for estimating travel demands for systems that are similar to existing facilities and services. There are, however, effects of significantly different transportation systems that are not adequately predicted by simply changing travel time, travel cost, service frequency and accessibility variables. These effects include: traveler perceptions of safety, comfort, convenience and amenities associated with a new high-quality service; the effects of induced development within the corridor; and improved accessibility to activity centers outside the immediate study area. To obtain a better understanding of these perceptions, market surveys were conducted to identify the relative importance of factors people consider when choosing a method of travel, such as comfort, convenience, reliability, perceived safety and other service characteristics that are difficult to measure. These characteristics are more related to the perception of the method of travel itself than to other factors such as travel time, access time, cost, and frequency of service that are also considered in the mode choice decision. A market research technique was adopted to provide a quantitative measure of the public's response to the implementation of a new rail service.

Conduct Surveys

To help develop mathematical models for estimating and projecting future high speed rail travel demand, two types of surveys were conducted. The major purposes of these travel surveys were to:

- Improve knowledge of existing travel and travel characteristics.
- Obtain statistical information to calibrate trip generation/distribution computer models.
- Quantify the perceptions related to the introduction of a new mode of travel, high speed rail.

The survey of current travelers, designed to fulfill the first two purposes, addressed concerns that travel characteristics had changed from previously available (mid-1960's) data and gathered new information at the minor civil division level of detail rather than at the more general county level used in the Phase 1 study. Disaggregation by the five trip purposes was also necessary to develop constants for the trip generation/distribution mathematical models. The third purpose related to the traveling public's perception of what, to the vast majority of Pennsylvanians, is a completely unfamiliar mode of travel. How people react to the introduction of a "new mode" with its own attributes of comfort, convenience and amenities, is of great importance in determining the projected mode split. These "market research surveys" were conducted separately and the results are presented in subsequent sections of this memorandum report.

The survey of current travelers consisted of an airline survey, a Pennsylvania Turnpike survey and an on-board Amtrak passenger survey.[1] The airline surveys were conducted at the Pittsburgh, Harrisburg and Philadelphia airports. A turnpike survey was conducted to obtain some insight into the travel characteristics of motorists who make relatively long-distance trips. A rail survey also was conducted to gain insight into the characteristics of existing rail users. In all, 25,538 questionnaires were passed out for all three surveys and 8,853 valid forms were returned for detailed analysis.

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[1] PBGF Memorandum Report dated July 30, 1985 entitled "Turnpike, Rail and Airline Surveys Conducted in May and June of 1985".

Market research surveys were conducted to define the variables that are important in the selection of the method of travel such as comfort, convenience, reliability, perceived safety and other service characteristics that are difficult to measure. Two market research surveys were conducted and included:

- A direct utility assessment (DUA) technique which provided a quantitative measure of the public's response to a new rail service relative to the existing transportation services.[2]
- A market research effort which provided quantitative and qualitative information on Pennsylvania travelers' needs and reactions to the concept of high speed rail service.[3]

The two market research surveys were conducted during the week of August 12, 1985; 85 people participated in the DUA and 125 people participated in the market research survey.

Obtain Expert Opinion

In direct support of the Pennsylvania High Speed Rail Study, the High Speed Rail Association formed a committee to evaluate requirements for forecasting and to write standard guidelines for revenue and ridership estimation. Although this expert opinion was available to all organizations developing revenue and ridership forecasts, the standard guidelines provided essential information for refining the operational concepts in this Pennsylvania study. These standard guidelines were followed in developing the Pennsylvania high speed rail revenue and ridership forecasts and included:

- The preparation and presentation of ranges in the forecasts.
- The use of multiple approaches to ridership forecasting in order to compare the resultant estimates.
- Establishing ranges for the variables to be used in the analysis and an understanding of how the variables affected the decision to select the optimum high speed rail system for Pennsylvania.
- Forecast detail that was required in estimating revenue and ridership forecasts.
- Tests of reasonableness that should be conducted to ensure that the results would be acceptable.
- The use of sensitivity testing to provide an understanding of the possible variations in the estimates due to different assumptions on

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[2] PBGF Memorandum Report dated October 22, 1985 entitled "Market Research Surveys Using Direct Utility Assessment Techniques".

[3] ORC Technical Memorandum on Market Research dated September 1985.

actions possibly to be taken by competing modes, the effect of real estate development in the vicinity of rail stations and its impact on high speed rail ridership, and the effect of other types of economic activity near high speed rail stations.

DATA COLLECTION

During the Phase 1 Study, 43 counties in Pennsylvania constituted the study area. This zonal system for Phase 1 was found to provide insufficient detail about the geographical distribution of activities to define adequately access and egress conditions. Therefore, for Phase 2, it was proposed to expand the number of zones to approximately 100. This expansion has improved the understanding of the distribution of socioeconomic and land use activities and travel conditions throughout the corridor. It was also decided to include three counties in Southern New Jersey that were closely affiliated with Philadelphia. Figure 2 shows the 108 analysis zones. Thirteen analysis zones, not shown on the figure, were added to represent areas outside the study area (i.e., Maryland, Delaware and Ohio). This enabled an analysis of external-to-internal trips and vice versa as well as through trips.

As a result of this redefinition of the study area, data were collected for these redefined areas, the physical characteristics of potential travelers were oriented toward the new zones, and existing travel patterns were also related to these 121 zones.

In addition, the rail network and access links, the air network and access links, and the highway network are all related to these new zones. The following sections provide a summary of the information collected and the analyses that were conducted with respect to these new zones.

Socioeconomic Data[4]

In each of the 108 analysis zones in Pennsylvania and New Jersey, minor civil divisions (MCD's) or municipalities (townships, boroughs, or cities) were identified. The data for the MCD's in each zone were aggregated to obtain zonal totals. Information on the following nine variables for each zone for both the base year (1980) and projection year (2000) was gathered or developed for use in the patronage estimating models:

- Area
- Total population
- Number of families
- Labor force
- Civilian employment
- Number of hotel and motel rooms
- College enrollment
- Average per capita income
- Average family income

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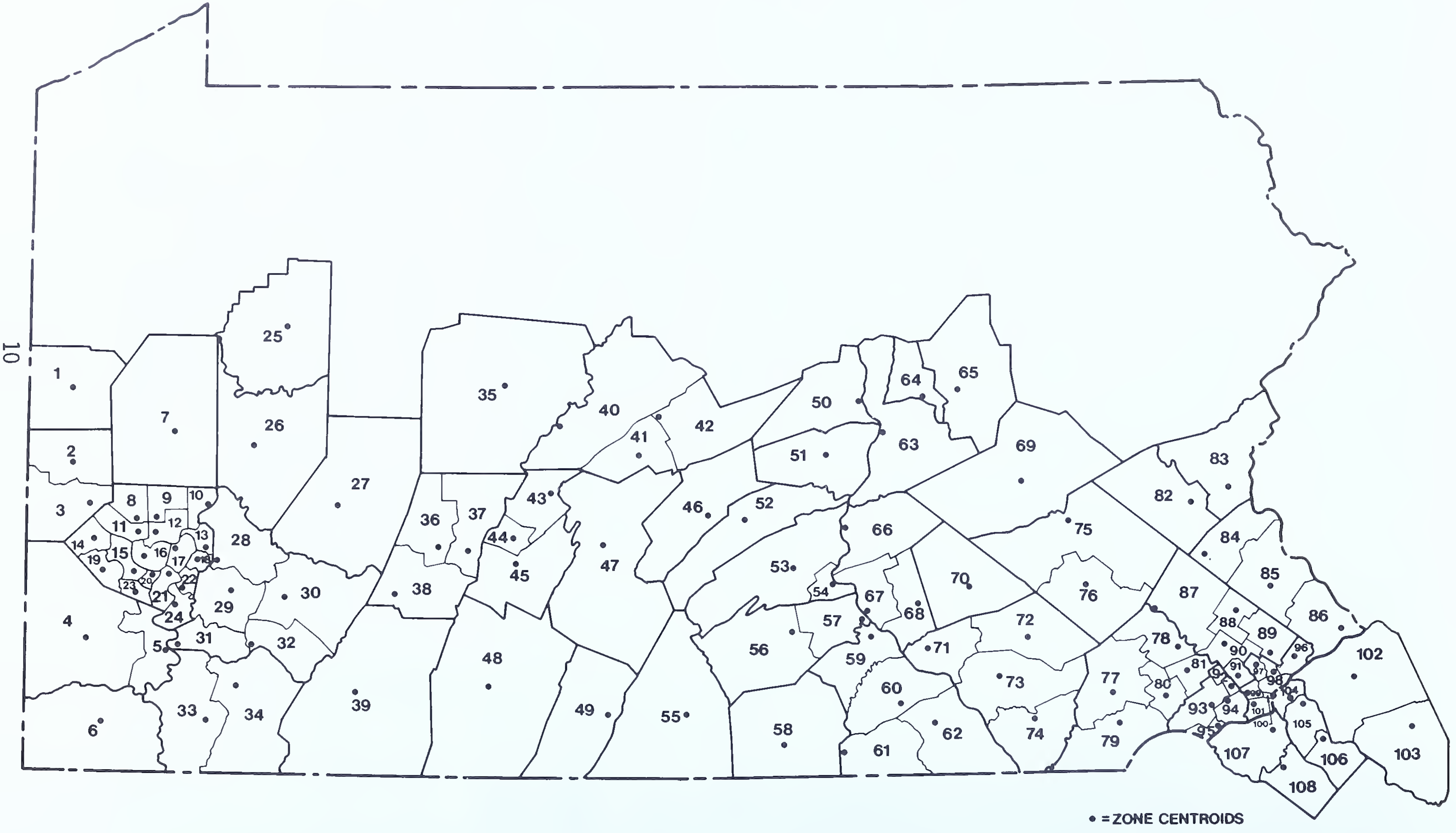
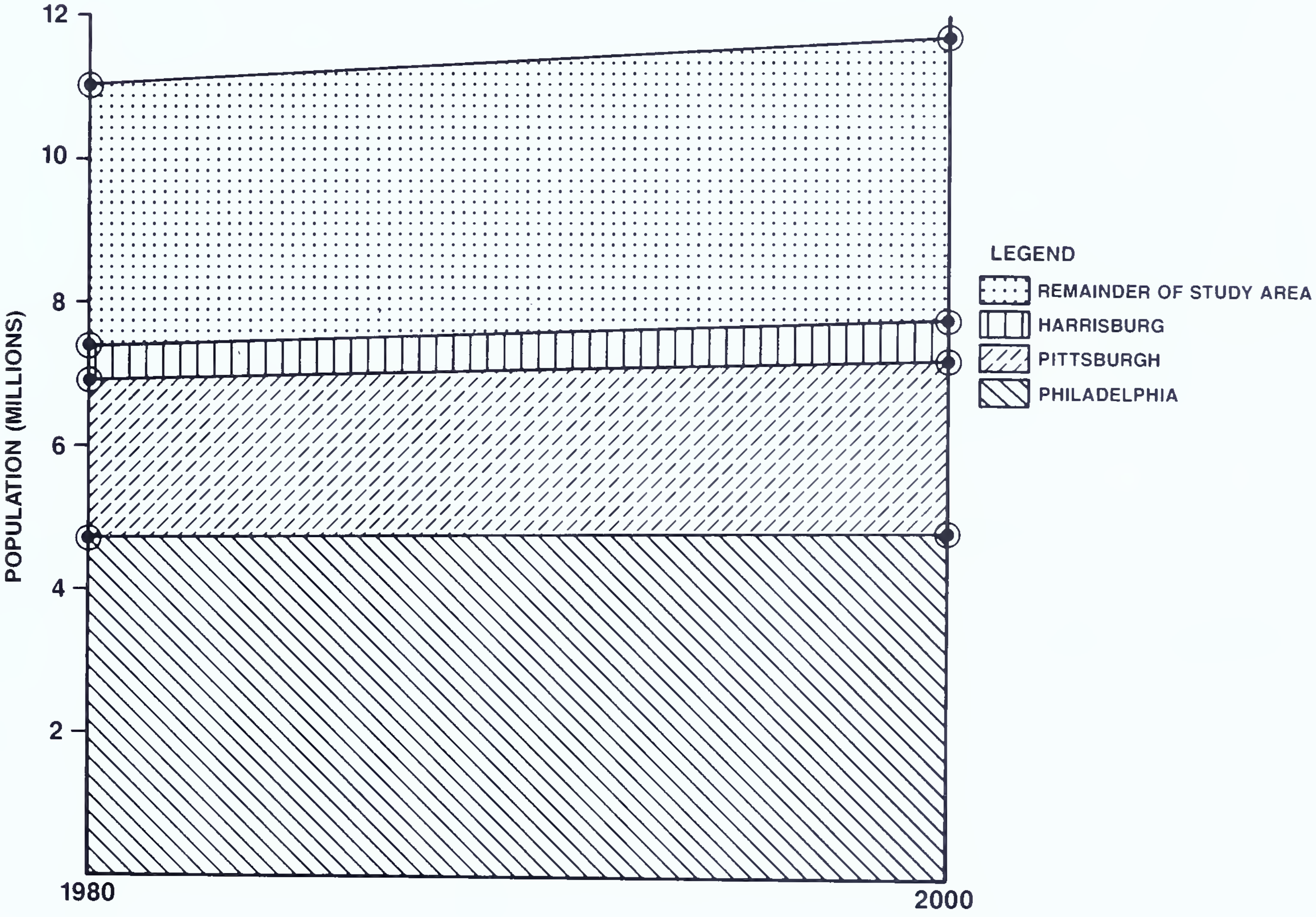
[4] PBGF Memorandum Report dated August 1985 entitled "Development of Socioeconomic Data".

FIGURE 2
STUDY AREA & ASSOCIATED ZONES



The resulting estimated population growth within the study area is summarized on Figure 3. Population is expected to increase from approximately 11.0 million in 1980 to 11.7 million in the year 2000. This relatively consistent growth of approximately .3% per year has been observed since 1960 and therefore the projections are consistent with observations over the past 20 years. The Philadelphia SMSA population is expected to increase from approximately 4.7 million in 1980 to 4.9 million in the year 2000. The Pittsburgh SMSA is expected to increase in population from about 2.3 million in 1980 to 2.4 million by the year 2000. The Harrisburg SMSA is expected to increase by the highest percentage from about .45 million in 1980 to .54 million by the year 2000 (.9% per year).

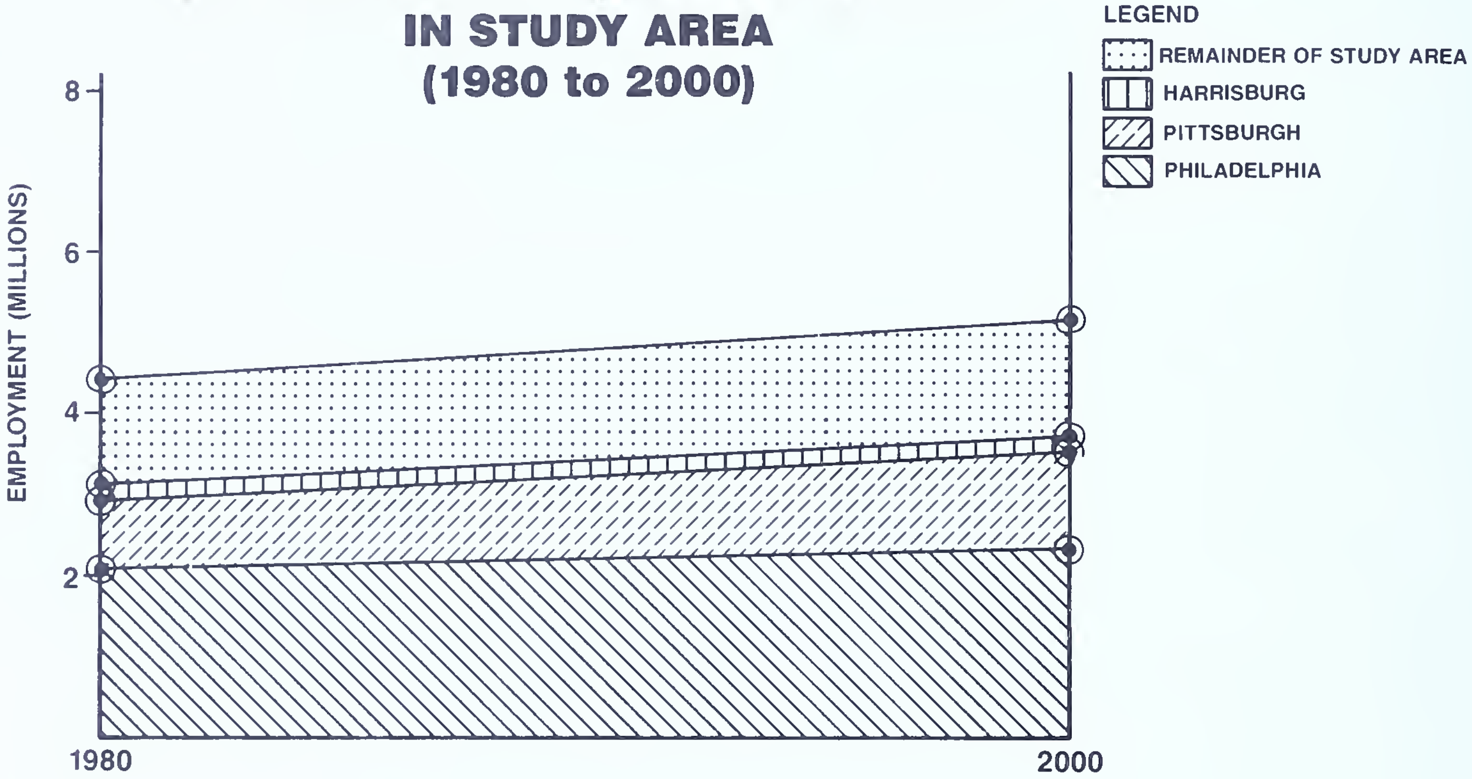
FIGURE 3
ESTIMATED POPULATION GROWTH IN STUDY AREA (1980 to 2000)



The resulting estimated employment growth in the study area is illustrated in Figure 4 and is expected to increase from approximately 4.5 million in 1980 to 5.2 million by the year 2000. The relatively consistent growth of approximately .7% per year has also been observed since 1960. Employment in the Philadelphia SMSA is expected to grow from approximately 2.1 million in 1980 to about 2.4 million by the year 2000. Pittsburgh SMSA employment is expected to grow from about .9 million in 1980 to 1.2 million by the year 2000. Within the Harrisburg SMSA, employment is expected to grow from about .2 million in 1980 to nearly .3 million by the year 2000.

FIGURE 4

ESTIMATED EMPLOYMENT GROWTH IN STUDY AREA (1980 to 2000)



This socioeconomic data provided one basis for the development of the trip generation/distribution models.

Vehicle Characteristics

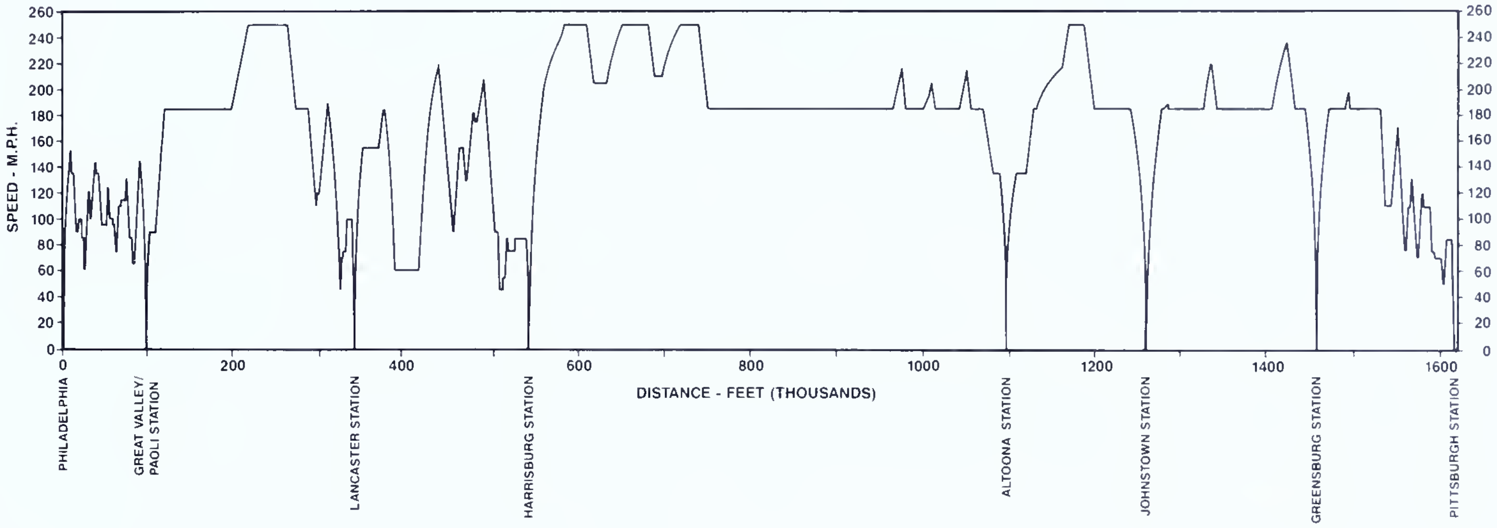
Representative vehicle characteristics were developed for each of the alternatives; these were used to estimate station-to-station and total travel times between Philadelphia and Pittsburgh. Characteristics included maximum acceleration and deceleration rates, number of driving axles, weight of the train, tractive effort curves, length of the train, the frontal area, coefficients for resistance, and wheel-to-rail adhesion. These factors then were entered into a computer train performance model to estimate both high speed rail and maglev performance, and to develop station-to-station travel times.

Alignments and Train Performance Modeling

A train performance computer model was used to generate travel times and energy consumption for each of the high speed rail alternatives. This computer model used vehicle acceleration, deceleration, and tractive effort versus speed data and guideway/track alignment, grade, station/stop location, and speed restriction data to simulate the speed of either a single vehicle or a train over the specific alignment. The maximum grade, minimum grade, increment in the grade to be considered, intermediate station dwell times, and horizontal and vertical alignments were used in developing station-to-station travel times. A sample output from this computer model is illustrated in Figure 5 and the speed in miles per hour versus travel distance was plotted to provide a speed profile throughout the whole alignment from Philadelphia to Pittsburgh. The computer output of the station-to-station travel times was then used as a major input into the market demand estimation computer model.

FIGURE 5

TRAIN PERFORMANCE MODEL SAMPLE SPEED PROFILE

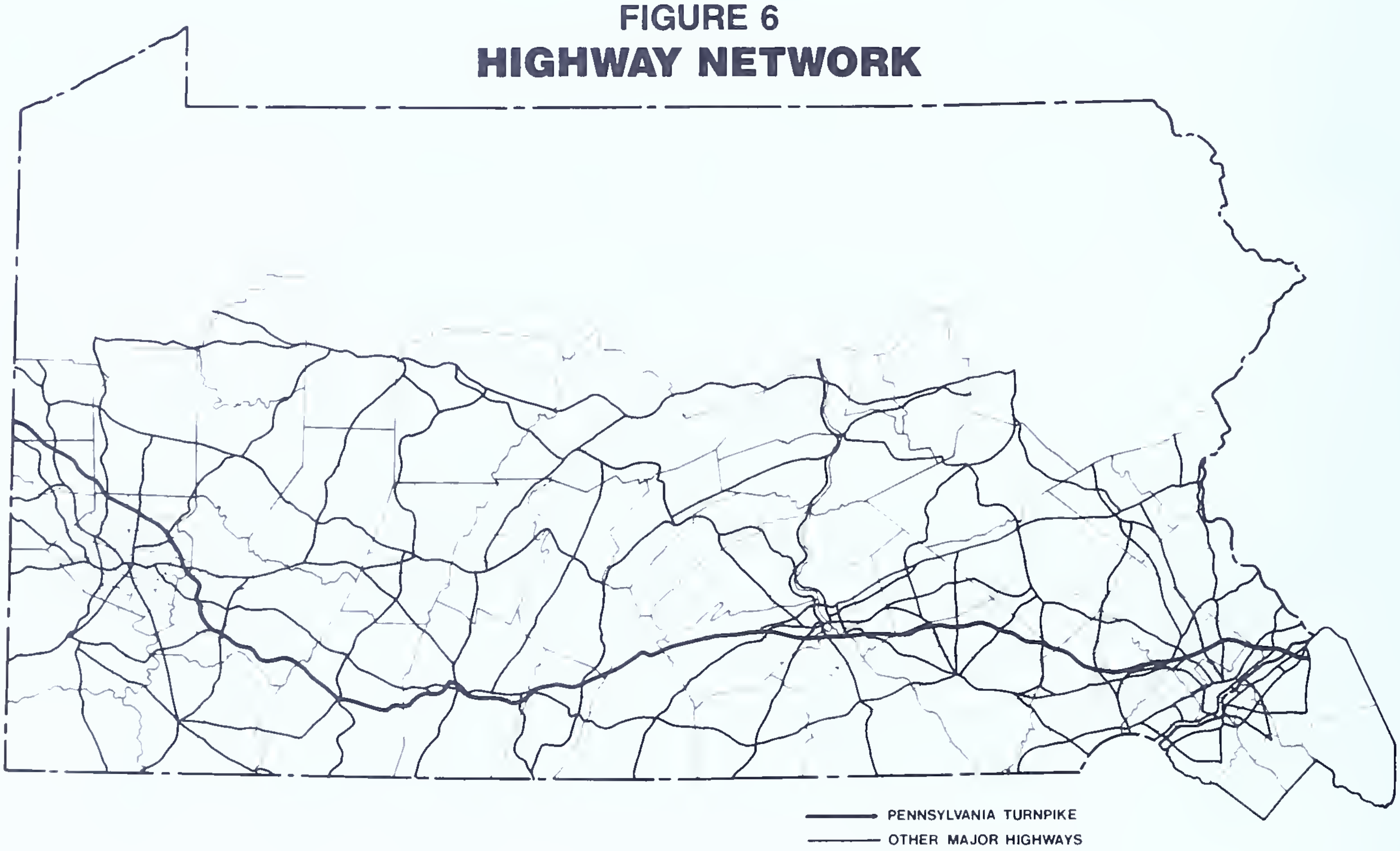


Physical Characteristics

The physical characteristics of each of the primary transportation alternatives were developed by establishing separate transportation networks. These networks were projected for the year 2000 and it was assumed that intercity travel patterns for the auto, rail and air travel modes will remain similar to those of today. Because the bus network is more flexible, it was difficult to predict routing and service changes between the base year and the projection year. Since level of service assumptions were necessary for the modal split, the procedure developed assumed that the bus mode's level of service (cost and travel time) was developed as a function of the existing highway network characteristics.

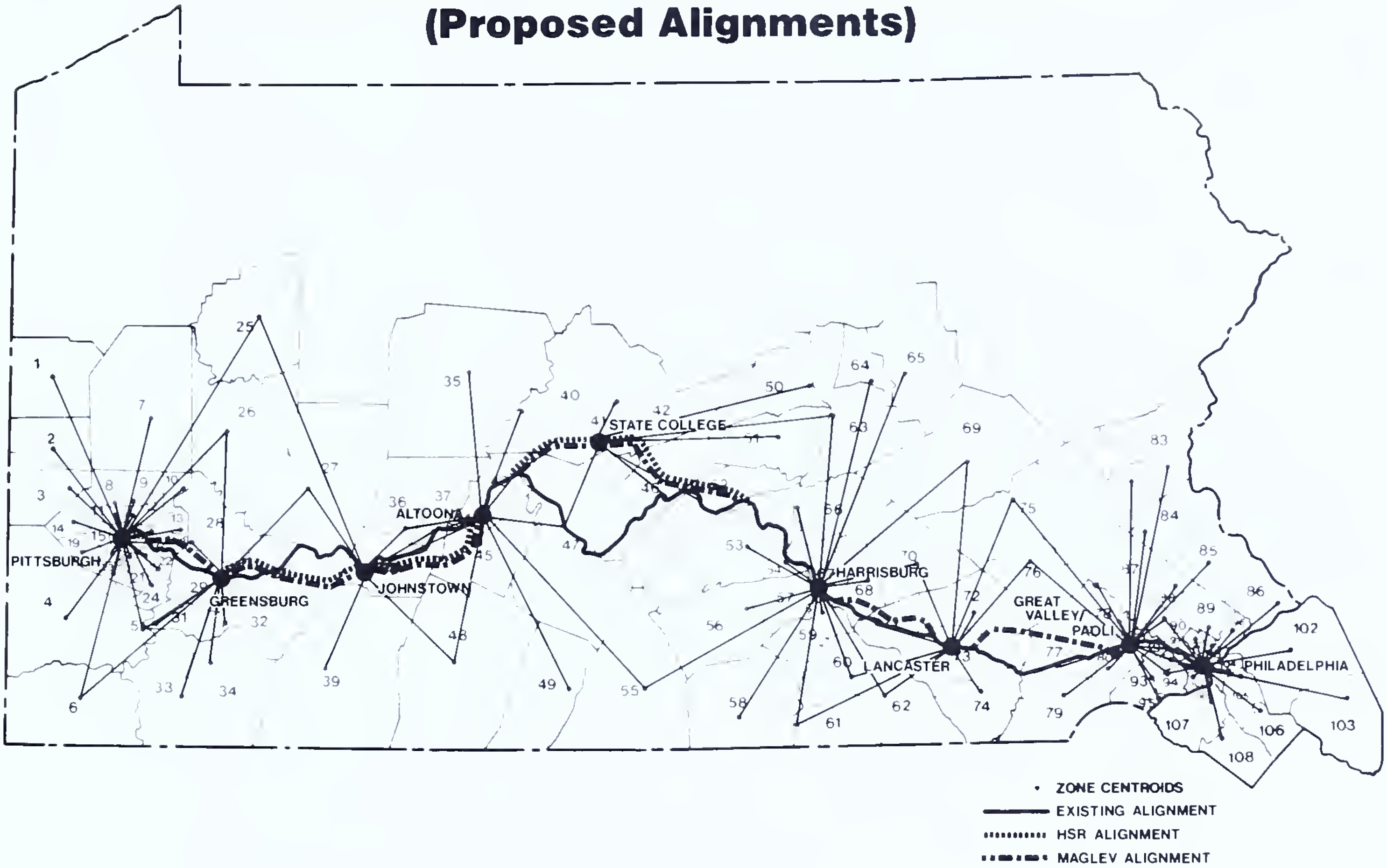
The highway network consists of all major east-west roads and highways in the study area that represent competitive alternatives to any high speed rail service plus major north-south routes that act as potential feeders to east-west facilities. After these facilities were identified, they were abstracted for computer representation by a series of nodes and links. The characteristics of each link such as distance, travel speed and classification were identified to complete this description, and the results are illustrated in Figure 6. The network was connected to the zonal centroids representing the study area zones by means of access links. These access links were created by a computer program which calculates the straight-line distance to the nearest network nodes and writes the access links in the format required for the computer program. This highway network is illustrated in Figure 6.

FIGURE 6
HIGHWAY NETWORK



The existing Amtrak service between Philadelphia and Pittsburgh provides the basis for the existing rail network. In a fashion similar to that used for the highway network, the rail line was described as a series of links and nodes. The nodes represent rail stations while the links are coded to represent the distance and time between rail stations. The schedule of each train that traverses the network was also coded to identify which stations are serviced by each scheduled train. The access link provides connections between the zonal centroids and the rail networks. The dominant mode for access, based on survey results, is the auto mode, which comprises riders who drive alone, share a ride, or use a rental vehicle or limousine. The access links also were coded for rail travel with each link being adjusted to reflect average speed and distance of the road leading to each station. Since travel time is a primary variable for the impedance calculation and path selection, the access codings approximated the access times obtained from the rail survey. The access links that connect the study area zones to the high speed rail alternatives are shown in Figure 7. These future access links were coded using the same procedures developed for the base year access links.

FIGURE 7
RAIL NETWORK AND ACCESS LINKS
(Proposed Alignments)



The air network represents the air service provided at 13 airports in the study area for both Class 1 carriers and commuter airlines. The nodes represent airports while links are coded to simulate travel time and distance between airports. The airports that are served on each flight were coded and Figures 8 and 9 show the air network and access links.

Existing Travel Patterns

The existing travel patterns are illustrated in the desire line diagram in Figure 10. This information provided estimates of the total person-trips for the 1980 base year. This information illustrates that the major travel in 1980 was concentrated in the Philadelphia, Harrisburg and Pittsburgh areas and between Harrisburg and Philadelphia.

FIGURE 8

AIR NETWORK

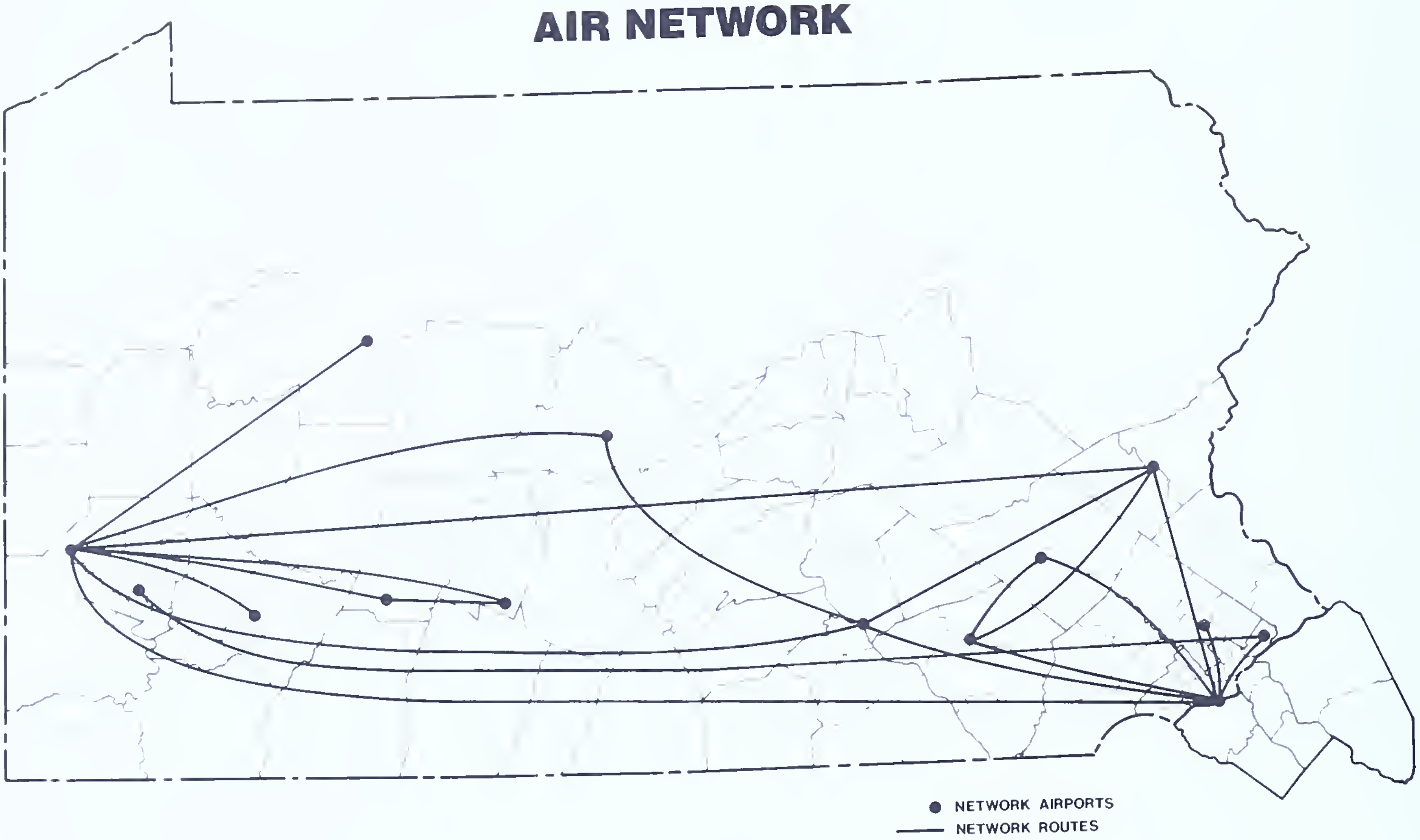


FIGURE 9

AIR ACCESS LINKS

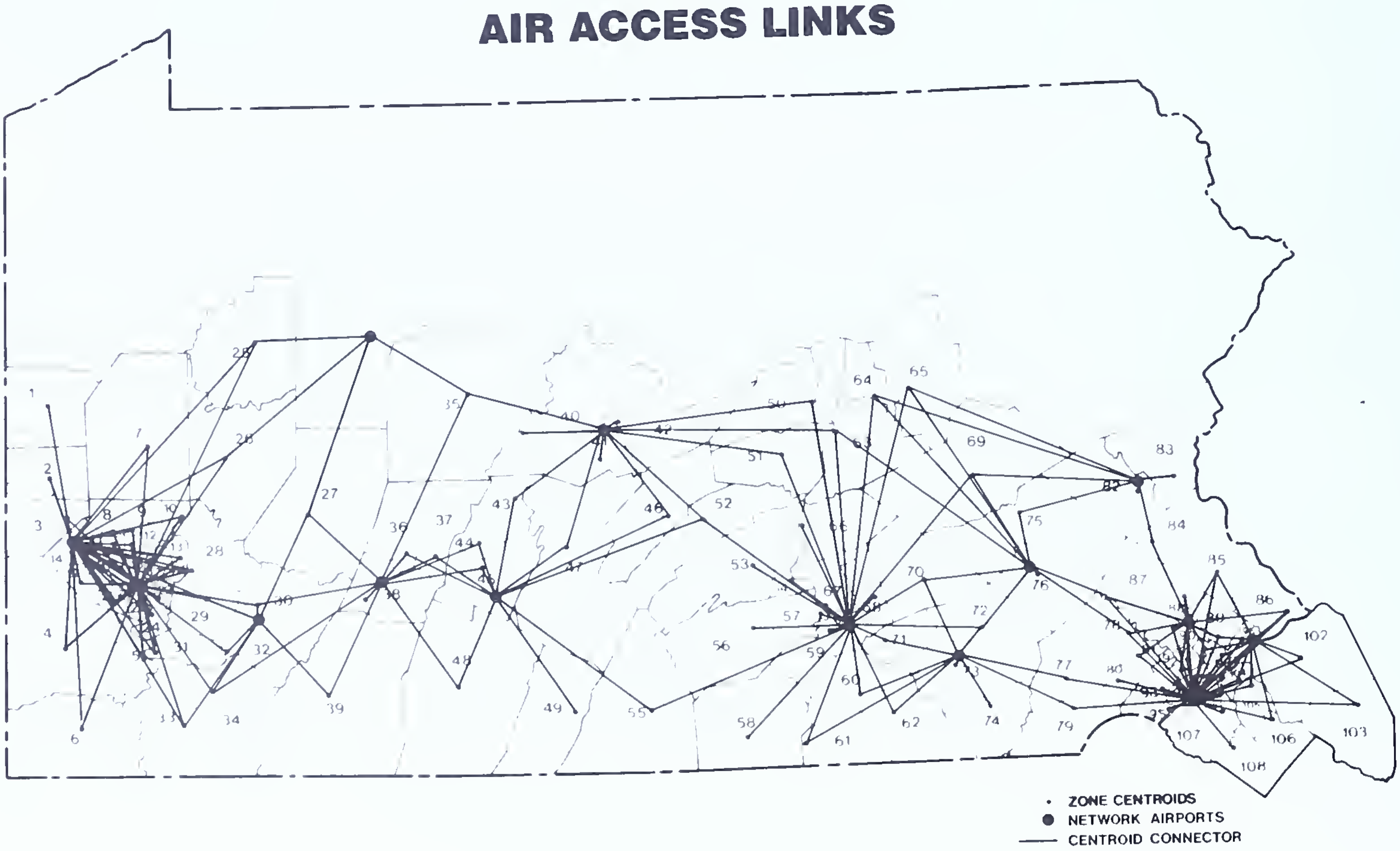
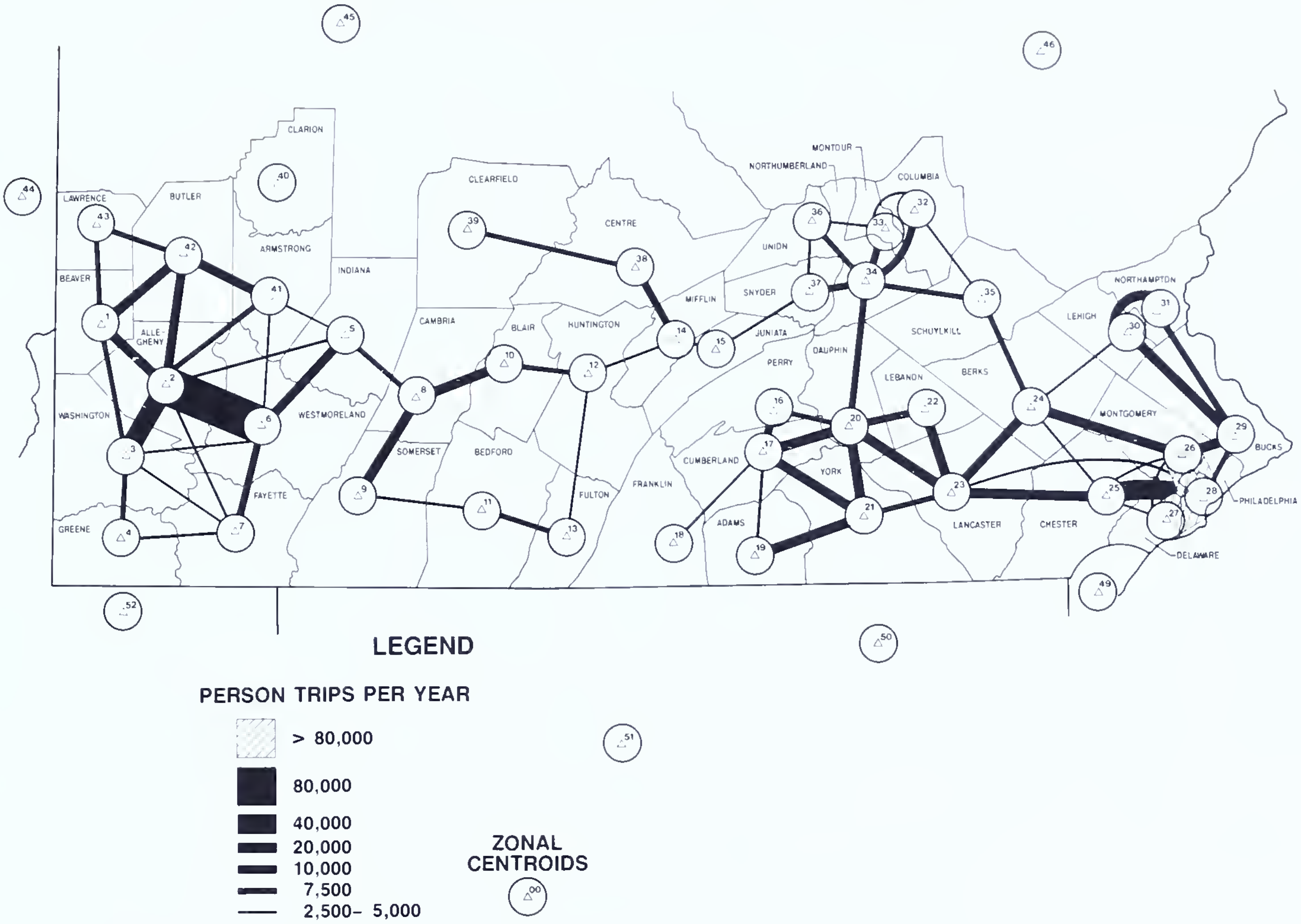


FIGURE 10
DESIRE LINE DIAGRAM TOTAL PERSON TRIPS 1980 BASE YEAR CONDITIONS



The 1985 turnpike, rail and airline survey results in Figure 11 indicate that there are about 5,000 long-distance daily trips between Harrisburg and Pittsburgh and between Philadelphia and Pittsburgh. These long-distance trips were also calculated from the Bureau of Census Journey-to-Work statistics, as illustrated in Figure 12, and the results correlate well with the information obtained from the 1985 surveys.

In summary, it can be observed that the majority of travel is less than 2 hours in duration. Therefore, it was assumed that if high speed rail travel between Philadelphia and Pittsburgh could be reduced to about 2 hours, travel by rail would be increased substantially.

Origin and Destination Survey Results

The turnpike, rail and airline surveys were conducted in May and June of 1985 (survey forms are attached at the end of the report). As noted, the purposes of the surveys were to improve knowledge of existing travel and traveler characteristics, to obtain statistical information that could be used to calibrate trip generation/distribution computer models, and to quantify the image factor related to the introduction of new modes of high speed rail travel.

FIGURE 11

1985 TURNPIKE, RAIL, AND AIRLINE SURVEY RESULTS

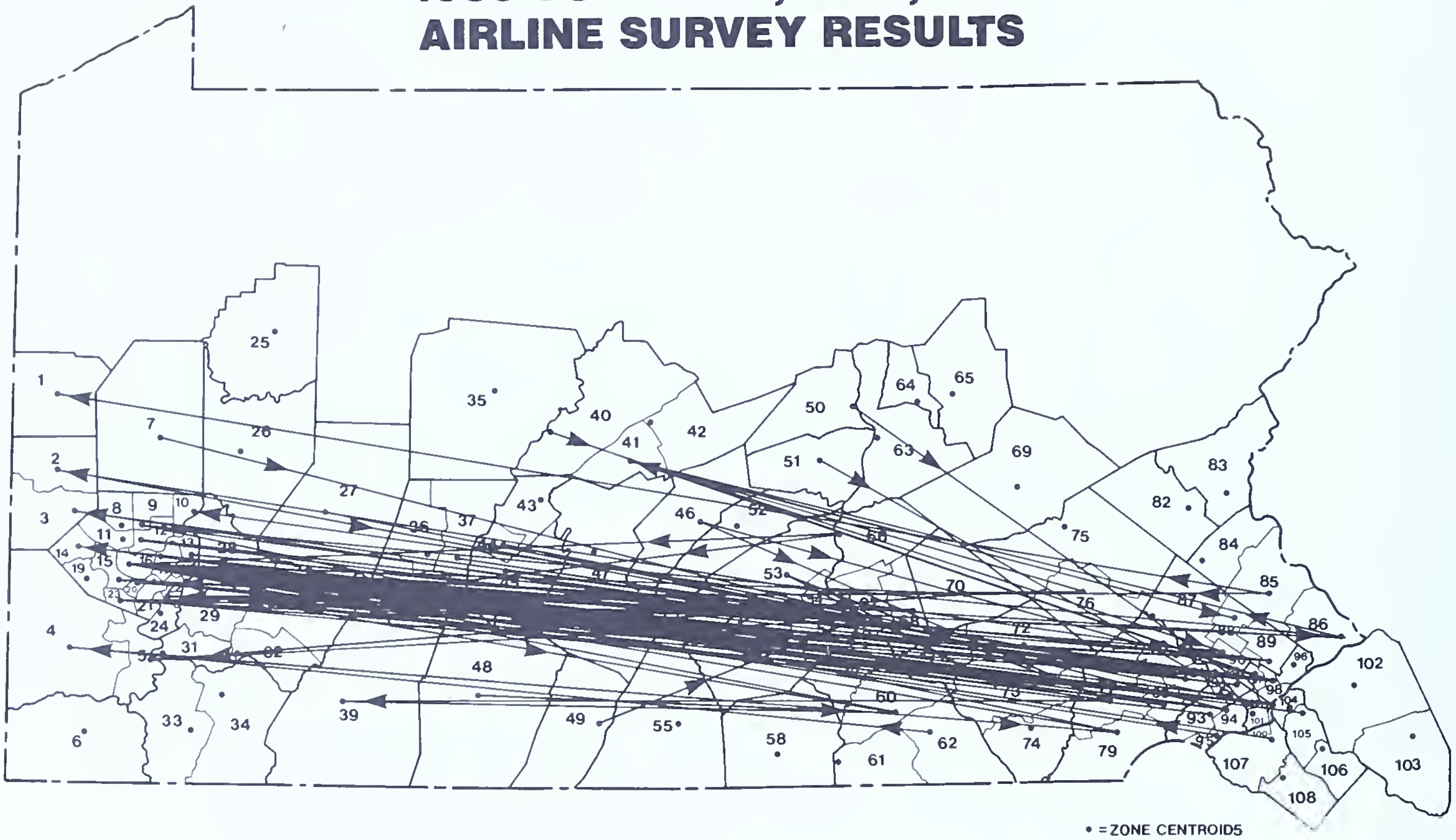
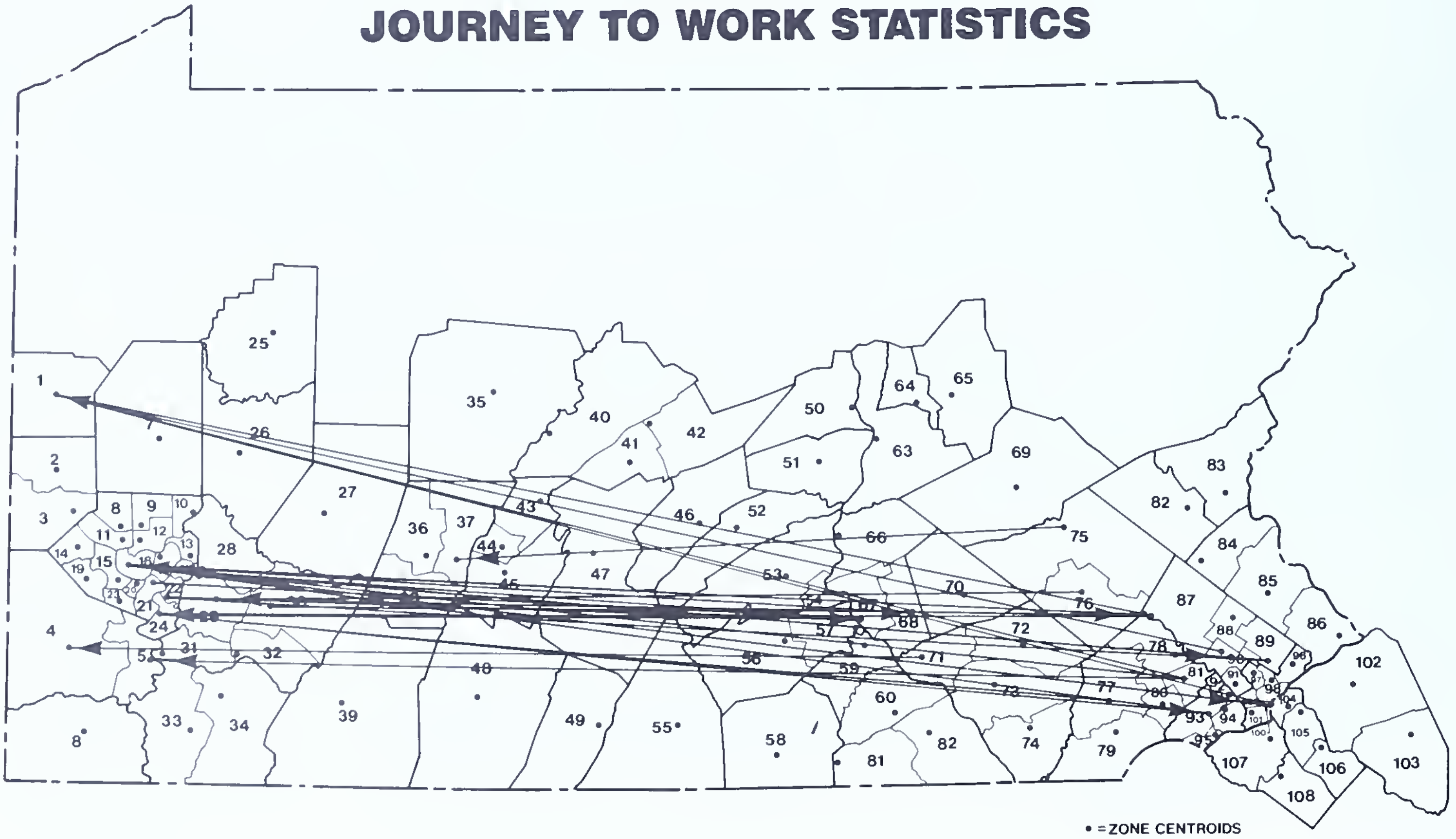


FIGURE 12

JOURNEY TO WORK STATISTICS



The "market surveys" were conducted separately using a focus group format and are discussed under "Direct Utility Assessment".

The airline survey was conducted at the Pittsburgh, Harrisburg and Philadelphia airports with all flights between the three airports being surveyed. Approximately 2,000 questionnaires were handed out to passengers while they waited to board their aircraft. Airline personnel provided actual ridership by flight, which permitted expansion of the survey data to include all air travelers. Approximately 59% of the survey forms were returned, which was about 25% of the total daily air ridership between the major cities in Pennsylvania.

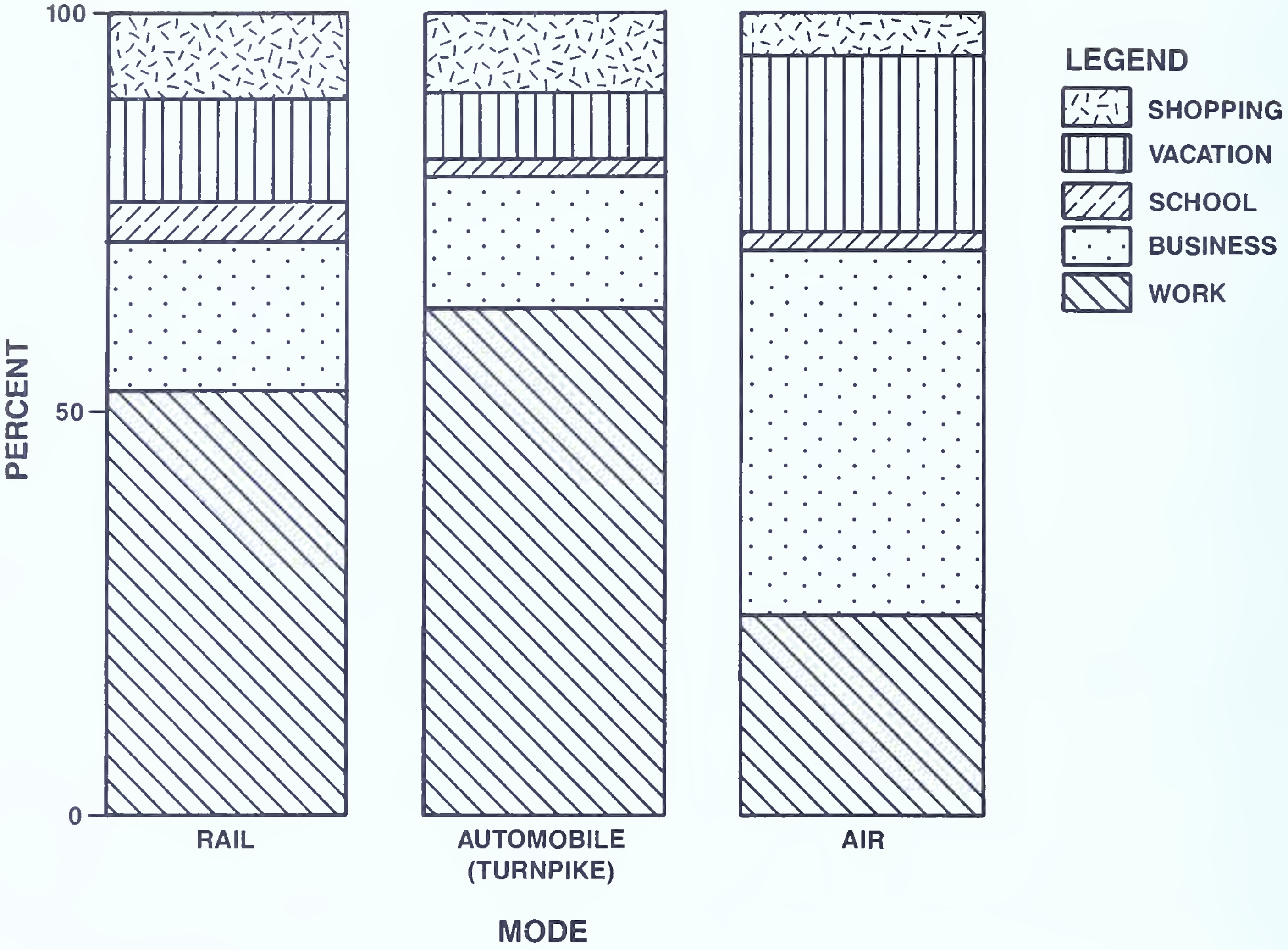
The rail survey was conducted aboard Amtrak trains; conductors provided ridership by train number. The passengers filled out the questionnaires enroute. These surveys were conducted during both weekdays and weekends to establish the differences in travel characteristics. The weekday survey resulted in nearly 2,300 forms being distributed to rail travelers, and a return rate of about 69% was achieved, or 38% of the total rail ridership during the survey period. The weekend survey provided about 1,300 forms to rail riders and a return rate of 69% was achieved for a 54% sample of the total number of rail riders.

Nearly 20,000 questionnaires were distributed to turnpike users, and about 26% of the survey forms were returned for additional analysis. The 20,000 survey forms provided to turnpike users was about 10% of the total vehicles using the turnpike on the day of the survey. The 22 highest volume interchanges, representing over 90% of the total turnpike travel, were selected with appropriate numbers of forms distributed at each interchange. The Turnpike Commission took an active role in conducting this survey and distributed the forms. The Turnpike Commission also provided a computerized output of origin/destination volumes during the day of the survey, which allowed expansion of the survey data to represent the actual daily volume on the turnpike.

A summary of the results of these surveys is provided in the following sections:

- Turnpike, Rail, and Airline Users Surveys. The results of these surveys were used to verify the concept of the computer models as well as some of the details used in model calibration. The surveys confirmed the existence and magnitude of the various types of trips such as work, business, school, vacation, and shopping trips. The survey results, shown in Figure 13, indicate that people are already using a rail service for these different types of trips. Approximately 52% of the current Amtrak rail riders were making work trips, 19% business trips, 5% school trips, 13% vacation/convention trips, and the remaining 11% were making shopping or "other" trips. On the Pennsylvania Turnpike, 62% of those surveyed were making work trips, 17% business trips, 2% school trips, 9% vacation/convention trips, and the remaining 10% were making shopping or "other" trips. The airline survey indicated that approximately 25% of the passengers were making work trips, 45% business trips, 2% school trips, 23% vacation trips and the remaining 5% were making shopping or "other" trips.

FIGURE 13
TRIP TYPE SUMMARY



The surveys indicated that most of the people making intercity trips had average family incomes that are well above the state median as shown in Figure 14. For example, the average family income for work and business trips was more than $40,000 per year; the average family income for school and vacation/convention trips was more than $30,000 per year; and the average family income for shopping, social or personal business trips was also more than $32,000 per year. The average family income of the air traveler was higher than for rail, which was somewhat higher than for the automobile users on the turnpike for most types of trips.

Additional results also indicated that most work and business travel by aircraft was paid for by an employer rather than by the individual, and that most rail and automobile travel was paid for by the individuals making the trips. However, even some rail and automobile trips were paid for by an employer rather than the individual, as shown in Figure 15. In general, the survey results indicated that more air travel is supported by businesses than either rail or automobile travel.

FIGURE 14
AVERAGE FAMILY INCOME BY TRIP TYPE

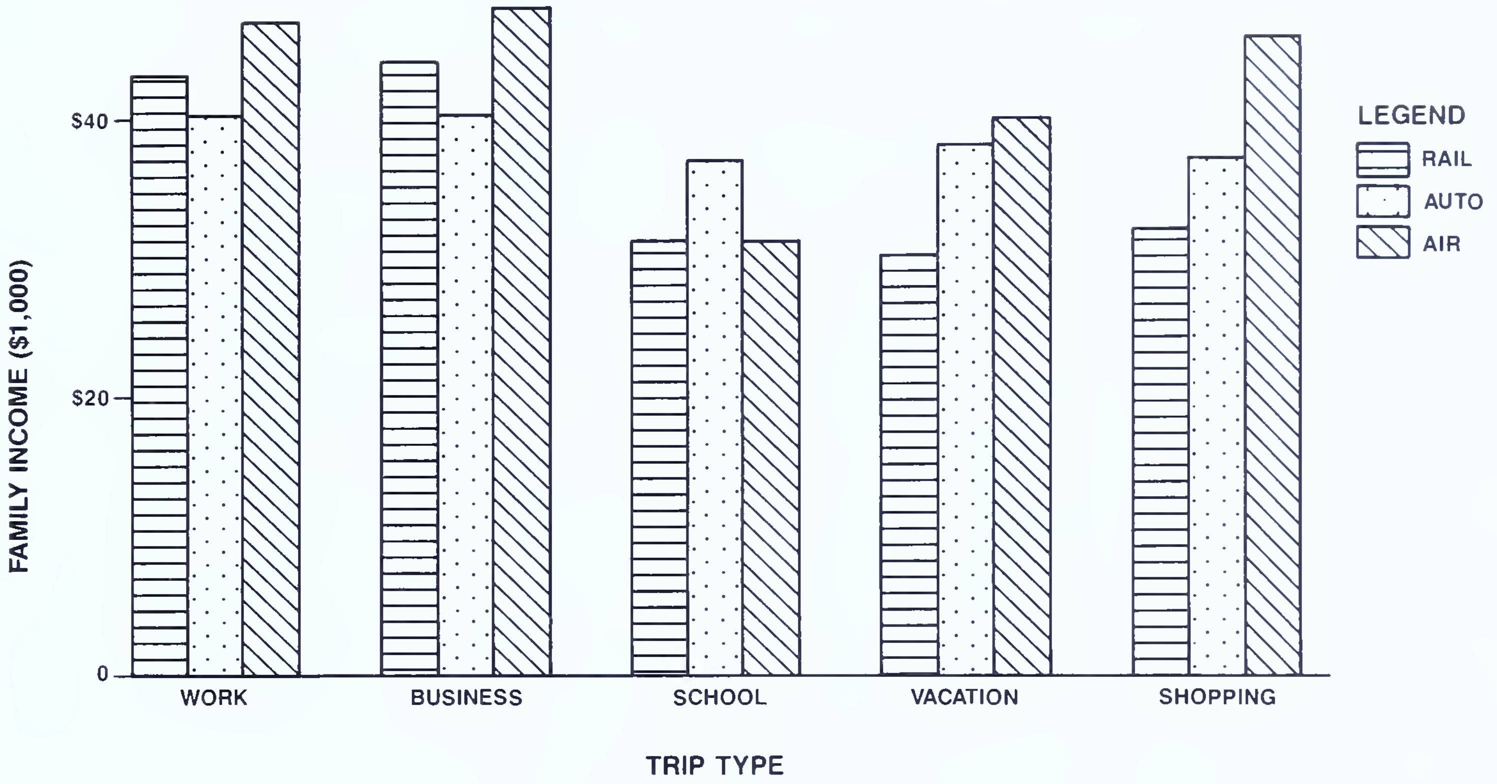
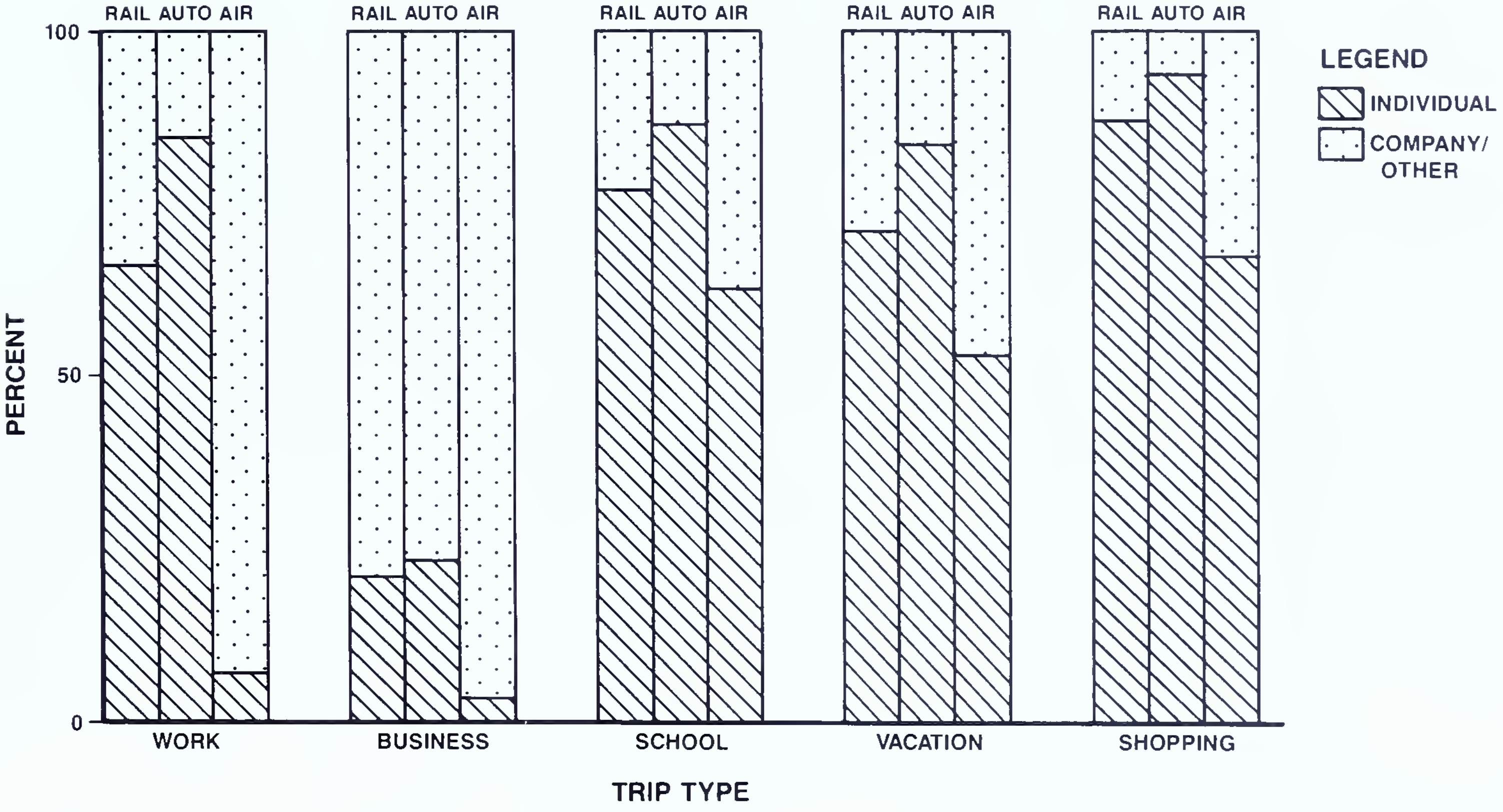


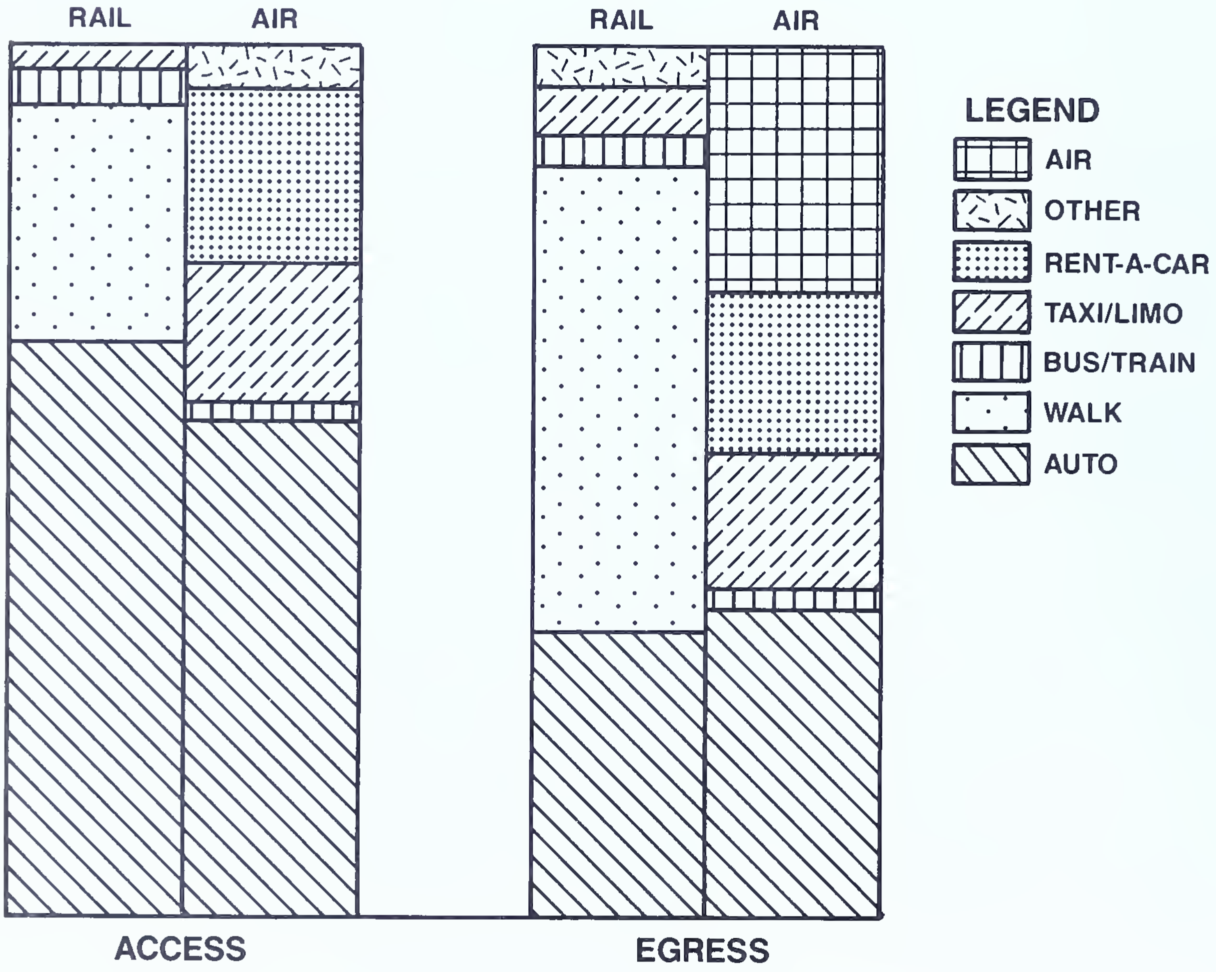
FIGURE 15
TRIP PAYMENT



The importance of intermodal connections at the various rail stations was obtained from the survey results shown in Figure 16. For example, most rail station and air terminal access was by automobile, but a relatively large percentage of air travelers used taxis/limousines or rent-a-cars. The station designs should therefore consider the parking that is necessary to support automobiles, rent-a-cars and taxis/limousines for both long- and short-duration trips. Station egress for the rail stations is predominantly by walking to the final destination although automobile users will require parking facilities.

The results of the travel surveys were used to validate trip generation and distribution computer models and to refine the information that was necessary to estimate total market demand for high speed rail. Of particular interest in this analysis is the fact that between 80% and 90% of the daily work trips were made more than three times per week while 6% to 18% of the business trips were made more than three times per week. The survey also indicated that approximately 30% of the school trips were made more than three times per week while most of the

FIGURE 16
STATION/TERMINAL ACCESS/EGRESS (Work Trips)



vacation/convention trips and shopping, social or other personal trips were made only occasionally. This trip frequency data was especially useful in obtaining a better understanding of the differences between work and business trips, and, with the origin-destination information, trip type probability versus distance curves were developed.

- Direct Utility Assessment. The DUA is a demand modeling technique based on obtaining responses to a series of hypothetical situations that have been constructed using an experimental design. The primary purpose of the DUA is to gain as much information as possible on the relative preferences for conventional rail, high speed rail, bus, automobile and aircraft travel. This statistical approach is desirable; from it, "numerical" values for different coefficients in the mathematical equations for different types of trips can be determined. The DUA responses are analyzed with multiple regression methods and when this technique is used, a travel alternative is represented by a group of attributes, including cost, travel time, access time, frequency of service, and the individual's preference for each mode (i.e., automobile, train, bus and airplane).

  The DUA's were conducted by using a focus group format. This method consisted of a series of one-hour sessions, each session having approximately 20 participants. A typical session began with a 15-minute audio/visual introduction to intercity transportation modes including a description of the high speed rail alternative as well as the existing highway, bus, aircraft and rail facilities. The visual introduction was then followed by 15 minutes of question/answer/discussion. At this point, the DUA experiment was administered and respondents took approximately 15 minutes to fill out the questionnaires. The DUA session was then concluded by answering any additional questions that the survey personnel had with respect to the different modes.

  Results from the DUA study could be used in any of several ways. On one extreme, the study could be used as the sole basis for specifying and estimating coefficients for the computer model. At the other extreme, the DUA data could be used simply to confirm the validity of an existing computer model. For the Pennsylvania High Speed Rail Study, the intention was to use the DUA study as the basis for updating selected modal coefficients; in particular, the mode bias coefficients. The DUA analysis provided the information necessary for the re-estimation of mode bias coefficients for the new high speed rail alternatives as well as for the other modes. In fact, the mode bias coefficients for existing modes generally should be adjusted so that the computer model actually replicates observed mode shares (i.e., the computer model was recalibrated by adjusting these coefficients). This means that the DUA estimates serve in either case primarily to place the high speed rail alternative in its proper ranking relative to the other modes.

Seasonal and Hourly Variations

The monthly variations for Amtrak and on the Pennsylvania Turnpike are shown in Figure 17. The turnpike shows the greatest variation, with relatively low usage during winter and very high usage during summer. Amtrak does not have nearly as much variation and actually has higher usage during winter than in summer. This analysis indicates that a high speed train should be able to compete most favorably with both aircraft and automobiles when the weather is bad due to ice, snow, rain and fog.

The hourly distribution of Pennsylvania Turnpike trips is shown in Figure 18. Although there is significant peaking between 7 A.M. and 10 A.M. and between 4 P.M. and 7 P.M. at the Pittsburgh interchange due to heavy commuter travel, the Gateway traffic counts show a more even distribution of travel between 8 A.M. and 11 P.M. Since high speed trains would not compete for short (less than 50 mile) commuter trips, the hourly travel shown for the Gateway interchange is considered to be more characteristic of the probable distribution of high speed rail travel.

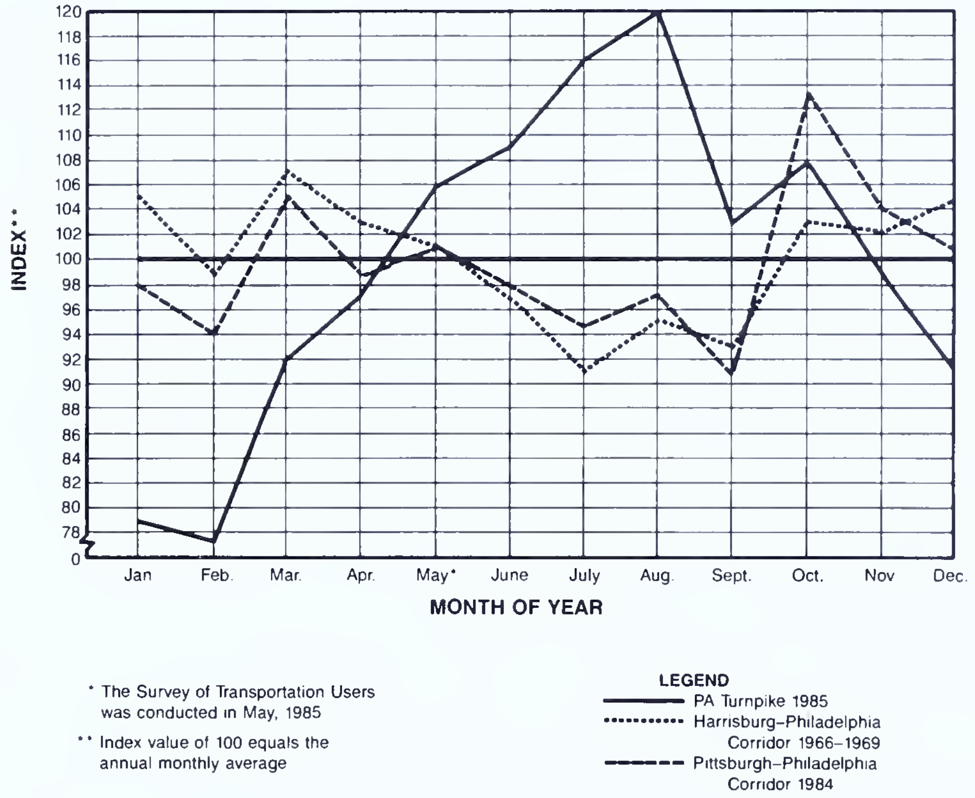
FORECAST DETAIL

In view of known uncertainties in projecting population, employment, cost, future state of economic systems, or of human behavior when presented with a new choice, a bounded projection technique was used for summarizing the final market demand estimates.

To minimize known uncertainties, major inputs into the market demand analysis were evaluated in detail so that questions commonly posed by the public, government officials and investors could be answered. These major inputs include the range of variation for each of the major variables used in developing the forecast; actual or perceived time and cost of travel; origins and destinations of current and future travelers; current total market by trip purpose; desirable service attributes; perceptions/fashionableness of the different modes; preference factors of the different modes; and other factors. In addition, some of the major assumptions are discussed in the following sections of this report.

- The Range of Variation for Each Major Variable Used in Developing the Market Demand Forecast. The more important variables include population, population density, employment, employment density, labor force, average family income, per capita income, college enrollment, and number of hotel/motel rooms. The estimated values for these variables are shown in Table 1 and it can be observed that the expected increase from 1980 to the year 2000 is relatively conservative for all of these variables. The greatest expected increases are for average family income and per capita income, which are expected to increase at a rate of 2.6% per year. Employment and employment density are expected to increase at a rate of about .7% per year and population and population density are anticipated to increase at a rate of about .3% per year. The only expected decrease is in college enrollment, which is related to known decreases in the number of high school graduates for Pennsylvania and New Jersey. These decreases were forecast by the college entrance examination board and other organizations.

FIGURE 17
MONTHLY TRAFFIC VARIATION FOR RAIL AND PENNSYLVANIA TURNPIKE



* The Survey of Transportation Users was conducted in May, 1985

** Index value of 100 equals the annual monthly average

FIGURE 18
HOURLY DISTRIBUTION OF TRAFFIC ON PENNSYLVANIA TURNPIKE AT SELECTED INTERCHANGES

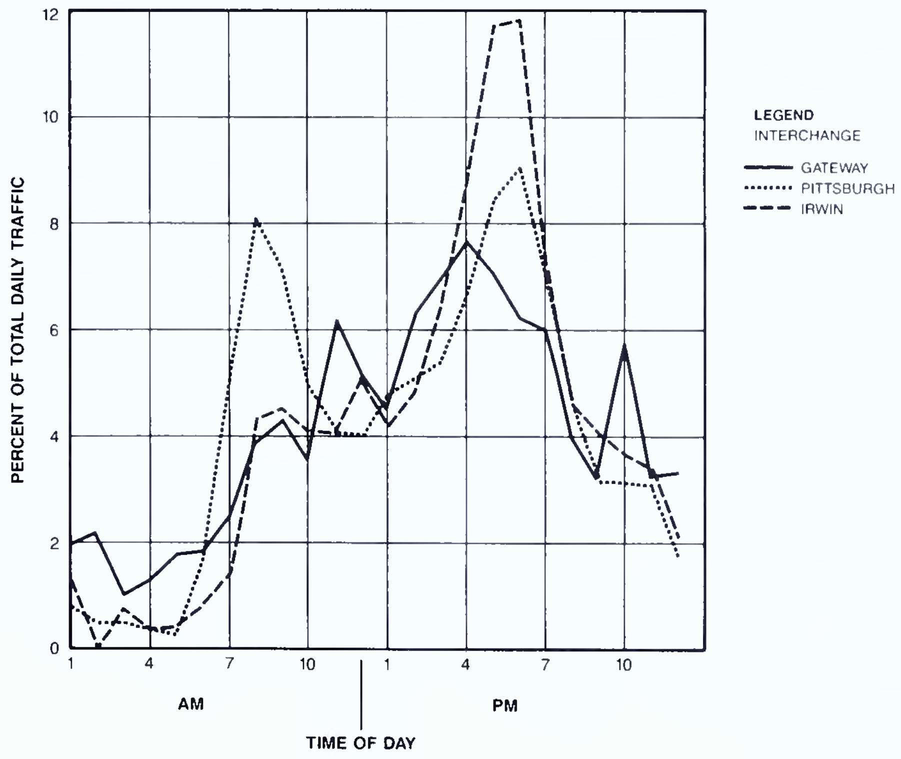


TABLE 1

Major Socioeconomic Variables

Variable	1980	2000	Ratio (2000/1980)
Area (sq. mi.)	28,154	28,154	1.00
Population	11,045,000	11,738,000	1.06
Population Density	392.3/sq. mi.	416.9/sq. mi.	1.06
Employment	4,481,000	5,151,000	1.15
Employment Density	159.2/sq. mi.	183.0/sq. mi.	1.15
Labor Force	5,103,000	5,441,000	1.07
Average Family Income	$27,000	$45,000	1.67
Per Capita Income	$7,200	$12,000	1.67
College Enrollment	482,700	346,300	.72
Number of Hotel/Motel Rooms	67,860	80,050	1.18

Population data were obtained from the 1980 U.S. Bureau of the Census (i.e., U.S. Census) information, except for the Philadelphia area. In Philadelphia, the city's zonal population was developed from Delaware Valley Regional Planning Commission (DVRPC) data. Census track numbers were assigned to each zone and, subsequently, totaled for each of the Philadelphia zones.

Population projections for the year 2000 were provided by the Southwestern Pennsylvania Regional Planning Commission (SPRPC), the Harrisburg Tri-County Regional Planning Commission and the DVRPC. The remaining zonal projections were calculated using the 1980 data and 2000 population growth factors from the National Planning Association (NPA).

The zonal labor force data were calculated from 1980 U.S. Census. The year 2000 projections were calculated by multiplying the 1980 data by the year 2000 zonal population growth factors derived by SPRPC, DVRPC, and NPA county level information.

Civilian employment data for the 1982 SPRPC area were adjusted to meet the 1980 totals by county as provided by the Pennsylvania Department of Labor and Industry. DVRPC and State Department of Labor and Industry information also was used for 1980. Projections were obtained from the SPRPC and DVRPC and derived for the remaining zones using 1980 State Department of Labor and Industry data and NPA county level civilian employment growth factors.

The sources of hotel/motel room data were obtained from the AAA, the Ziff-Davis Hotel and Travel Index, and the Pennsylvania Department of Commerce. Zonal civilian employment growth factors were used to calculate year 2000 projections.

The average per capita income data were derived from the 1980 U.S. Census and multiplied by county level average family size to yield 1980 average family income. The year 2000 projections were calculated using the 1980 data (in 1979 dollars) and 2000 NPA based growth factors. All income estimates were converted into 1985 dollars using escalation factors developed from the U.S. Department of Labor (Consumer Price Index - Urban Wage Earners and Clerical Workers) (all items).

While all of the major socioeconomic variables in Table 1 are considered to be relatively conservative, it was decided to use the year 2000 projections as the "base" estimate and the year 1980 values for the "lower bound" estimate to provide a reasonable range of values for the market demand analysis.

o Actual or Perceived Time and Cost of Travel. As previously explained, the mathematical model includes trip generation/distribution and modal split equations. Both equations were calibrated by using results obtained from the surveys and Journey-to-Work statistics.

The computer model requires variables in addition to the total cost and travel time for the trip generation/distribution model. Besides cost and travel time, the modal split model requires the access distance and frequency of service for each mode. These variables are often referred to as "level-of-service data" and were developed for each path in the transportation network. The level-of-service variables derived from the networks then were refined by adding the parking costs and terminal times for each travel mode. Access costs, the cost incurred from the trip origin or destination to the transit networks, were modified further by dividing the cost by the average number of people per vehicle making the trip. Information used to modify the level-of-service variables was available from the 1985 rail, turnpike and air survey conducted as part of the Phase 2 effort. The following paragraphs provide a detailed explanation for each of the level-of-service variables.

- Cost. The costs used in Phase 2 were adopted from the extensive research conducted during Phase 1. Results of the Phase 1 research produced the following formulas for bus and rail fare:

  Bus fare = 3.40 + 0.078 x (distance in miles)

  Rail fare = 0.87 + 0.110 x (distance in miles)

  Since the air cost could not be adequately calibrated to represent the observed cost data, the air fares were directly coded for each air route.

The auto costs were calculated and based on the perceived costs to the traveler. A value of 12¢ per mile was selected to represent the perceived costs. This value was adopted from several recent demand estimation studies.

For the air, bus, and rail networks the access costs were also included in the calculation. Results of the survey indicated that the dominant means of access was the automobile. The access cost values were calculated at 12¢ per mile. Parking charges for all travel modes also were added to the cost calculation. The values for parking ranged from $5 in the urbanized areas to $1 for less populated locations.

To develop the total travel cost per person, the transit modes' access costs were divided by the number of persons per trip, and then added to the transit fares. The auto travel cost per person was developed by dividing the total cost, including parking charges, by the number of persons per trip.

- Time. The total travel time values for each mode were calculated for both the trip generation/distribution model and the modal split model. For the trip generation/distribution process, the total time consists of the running time, access time, and terminal time. The modal split model treats the access distance as a separate variable, so the total time is the sum of only the running time and the terminal time. The values for running time and access time for each path were developed directly from the networks. The terminal times for rail and air travel were provided from the survey; the terminal values for these travel modes are 26 and 90 minutes respectively. The bus terminal time value was assumed to equal the value derived for the rail mode, due to similarities of the terminal characteristics, and a value of 10 minutes was adopted for auto terminal time. The auto terminal time represents the time spent parking the vehicle and walking to the final destination.

- Frequency. The frequency of service of each mode was developed for use in the modal split model. The frequency of service was defined by the scheduled service and assumed a 16-hour operating day. For auto travel, the frequency was defined as infinite, meaning that a potential traveler has immediate access to a vehicle. While this concept is not completely accurate, it is sufficient for use in this study.

- Access. The final level-of-service variable required for the modal split model is the access distance. Each path in the air, bus, and rail networks had values calculated to represent the distance traveled on the selected path to gain access to and egress from the transit facilities. The 1985 survey of transportation users, conducted as part of the Phase 2 effort, indicated that a large percentage of respondents used an auto to gain access to rail stations. Logically, the access values were defined by the adjacent highway network. A computer program was written to calculate distance, using network coordinates, with adjustments to reflect circuities of the actual roadway. The highway network access distance was set to zero since the distance to the vehicle at either end of the trip was considered to be minimal.

Although it was perceived that automobile, bus and airport travel times could be increased significantly by highway and airport congestion, it was decided that making assumptions on the degree of this congestion would be too arbitrary and controversial for this study. Therefore, it was assumed that intercounty highway and airport travel congestion would remain relatively constant, that the necessary highway and airport facility improvements would continue to be made, and that the actual or perceived travel time would not change significantly by the year 2000. These assumptions were recognized as being conservative, since all acceptable statistics indicate a potential increase in congestion and degradation in travel time.

- Origins and Destinations. The origins and destinations of travelers in Pennsylvania were obtained from the 1985 rail, air, and turnpike surveys. The results of this analysis are illustrated in Figures 19 through 21.

The study area and associated zones of rail origins from the survey are illustrated in Figure 19 and this information shows that, at present, most of the origins are from the zones in the eastern part of the state. Rail destinations are also primarily in the middle and eastern sections of the state due to the shorter travel times (i.e., less than 2 hours).

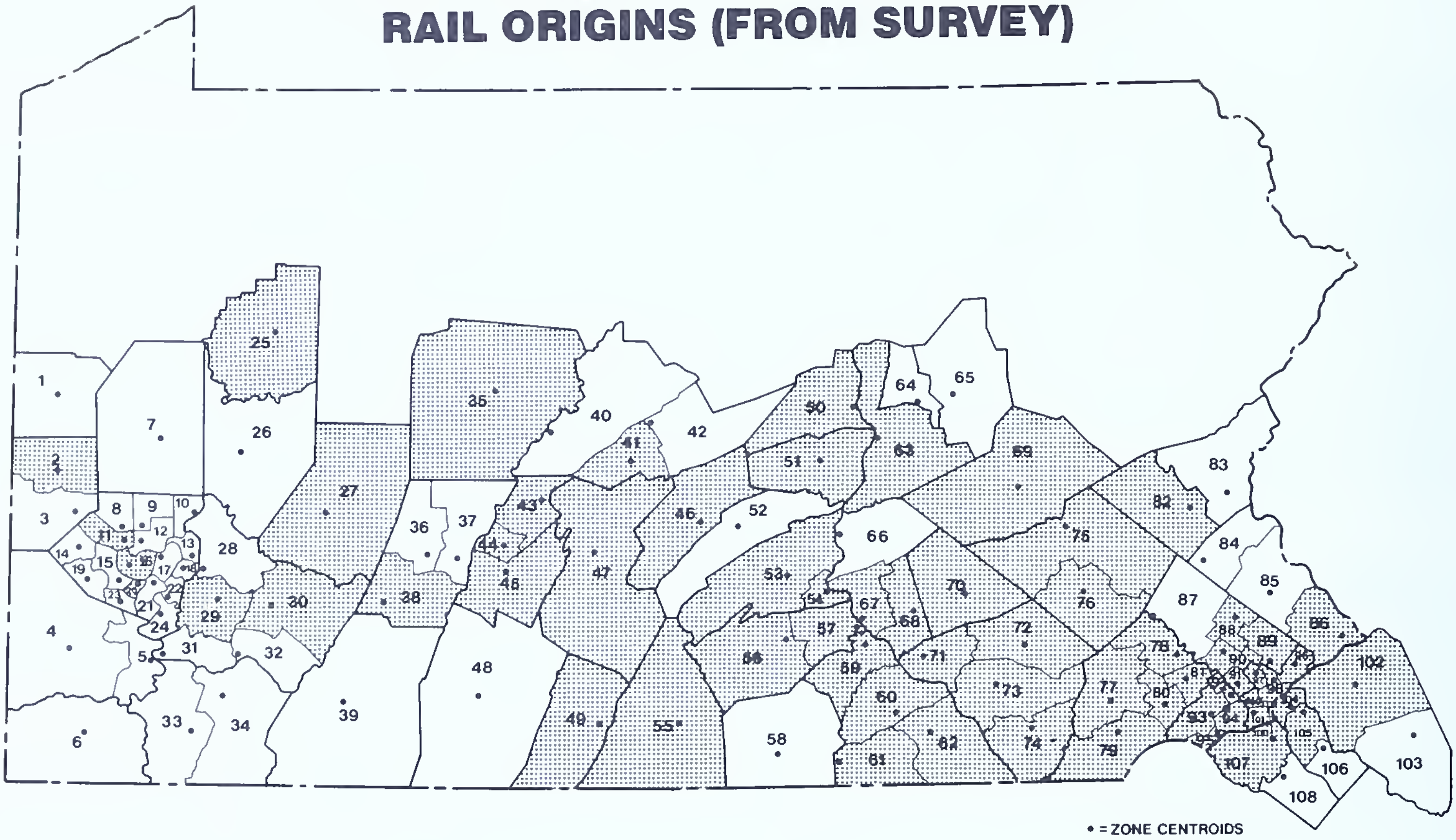
The study area and associated zones illustrating the air origins and destinations are shown in Figure 20. The air origins are concentrated near the major airports in Philadelphia, Harrisburg, and Pittsburgh where the surveys were conducted. The destinations are also primarily concentrated in these major metropolitan areas.

The study area and associated zones illustrating the turnpike origins and destinations are shown in Figure 21 and it can be observed that people living in most of the counties in the study area use the turnpike for travel throughout the state.

In summary, it was assumed that people from most of the study area zones would use a high speed rail system if the travel times were significantly reduced over existing travel time. This assumption was based on the fact that people throughout the whole study area use the major east-west turnpike corridor and that even the current rail system provides transportation to many of the zones throughout the state and study area.

FIGURE 19

STUDY AREA & ASSOCIATED ZONES RAIL ORIGINS (FROM SURVEY)



STUDY AREA & ASSOCIATED ZONES RAIL DESTINATIONS (FROM SURVEY)

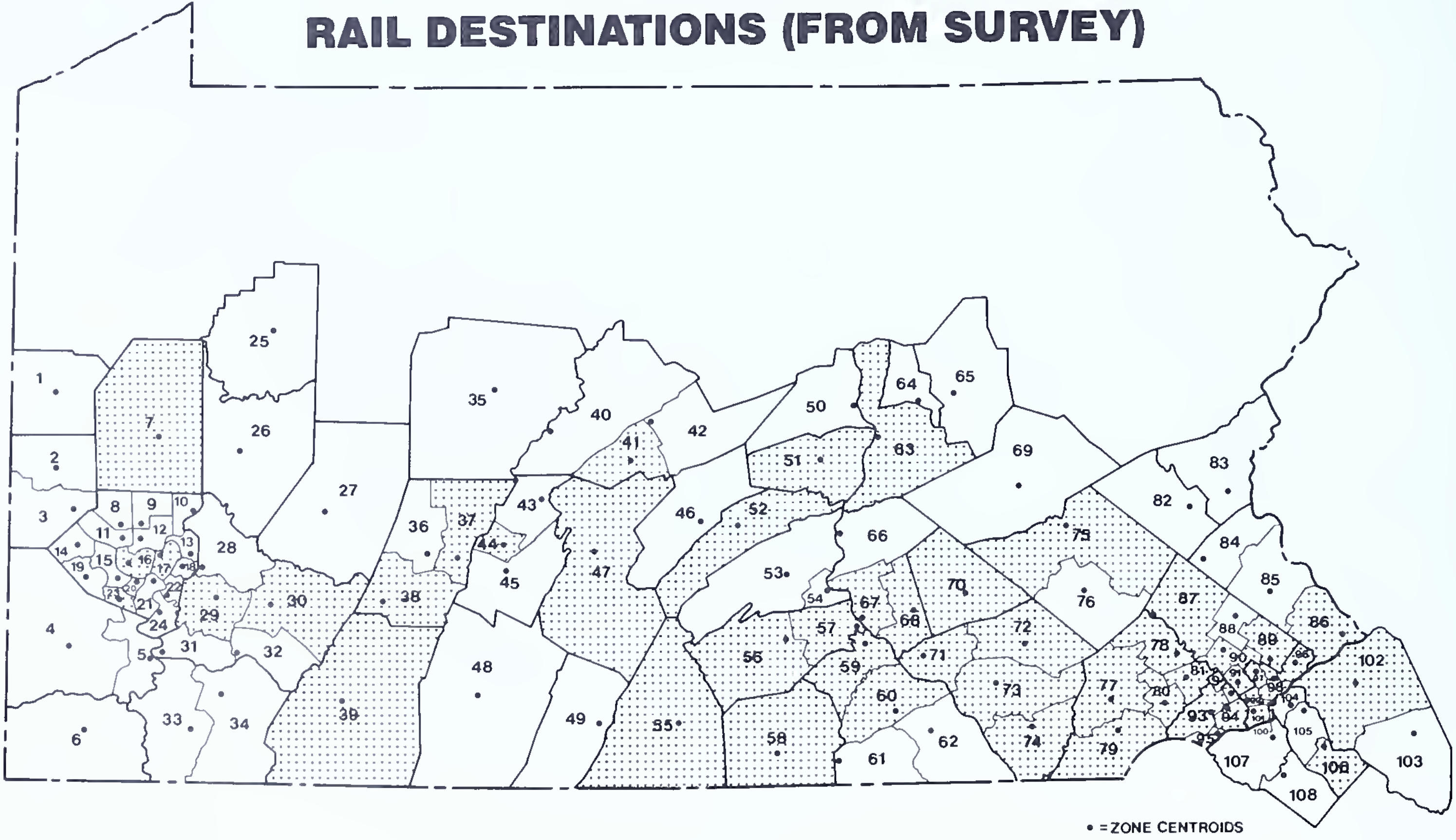
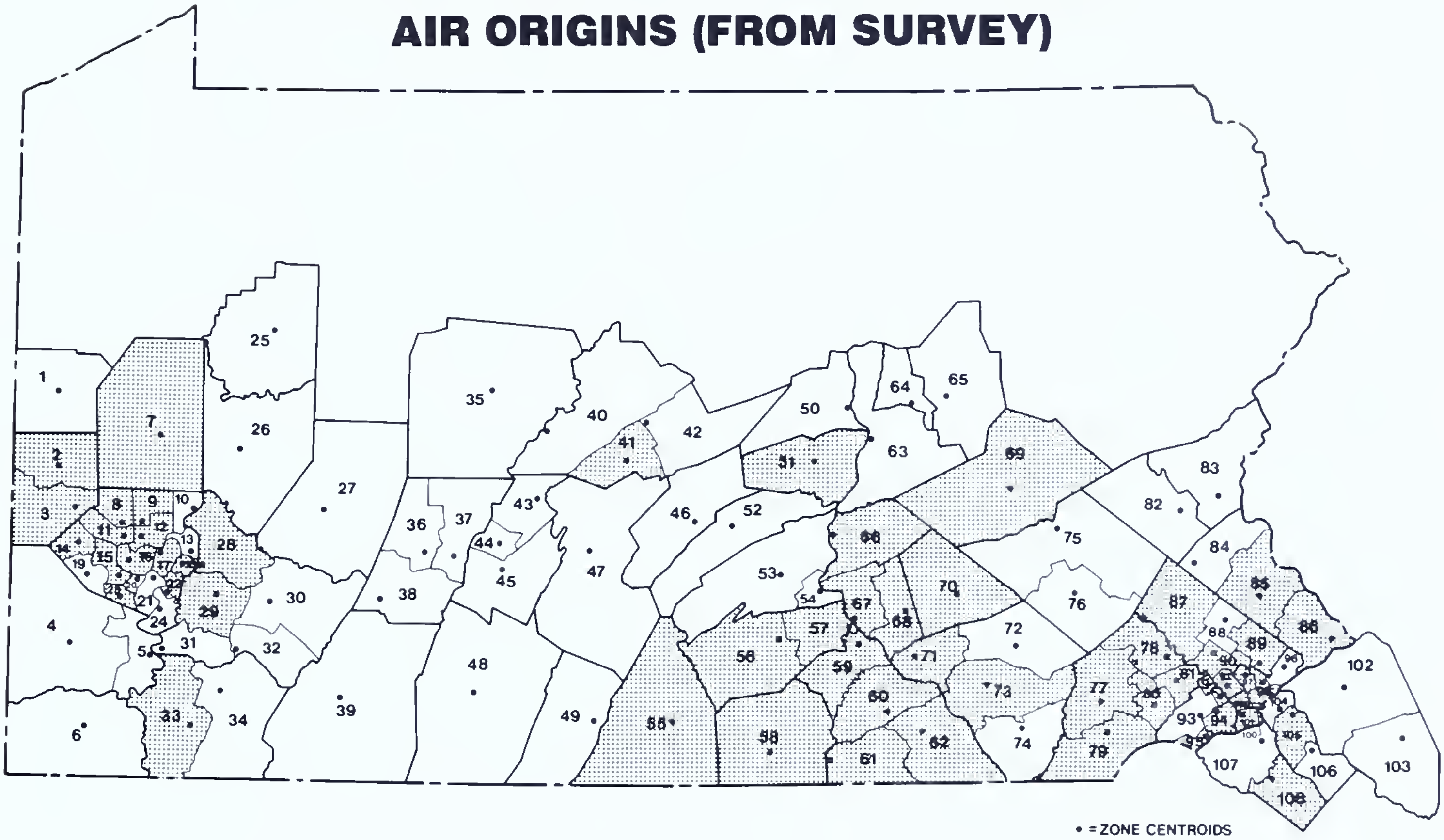


FIGURE 20

STUDY AREA & ASSOCIATED ZONES AIR ORIGINS (FROM SURVEY)



STUDY AREA & ASSOCIATED ZONES AIR DESTINATIONS (FROM SURVEY)

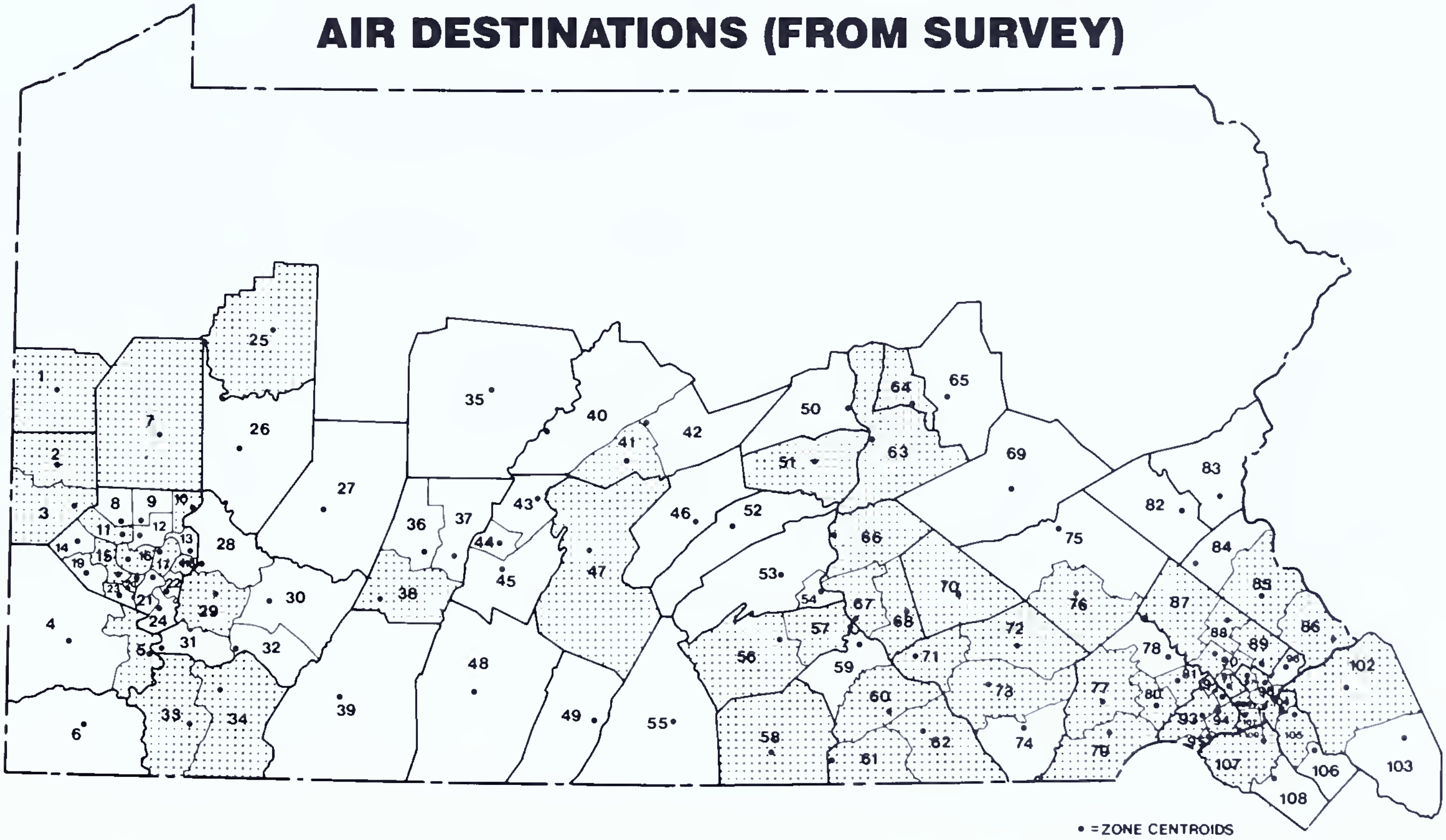
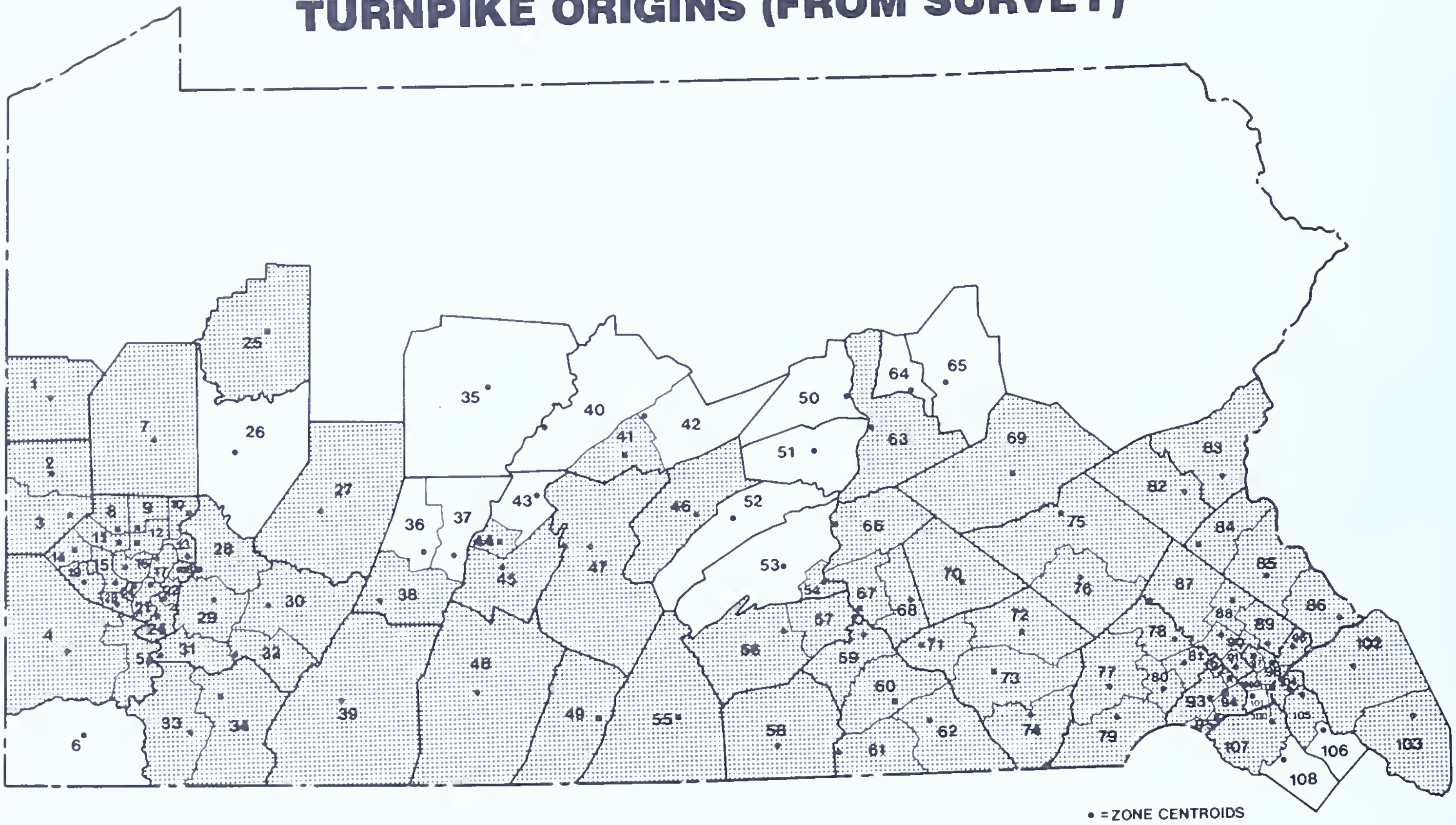
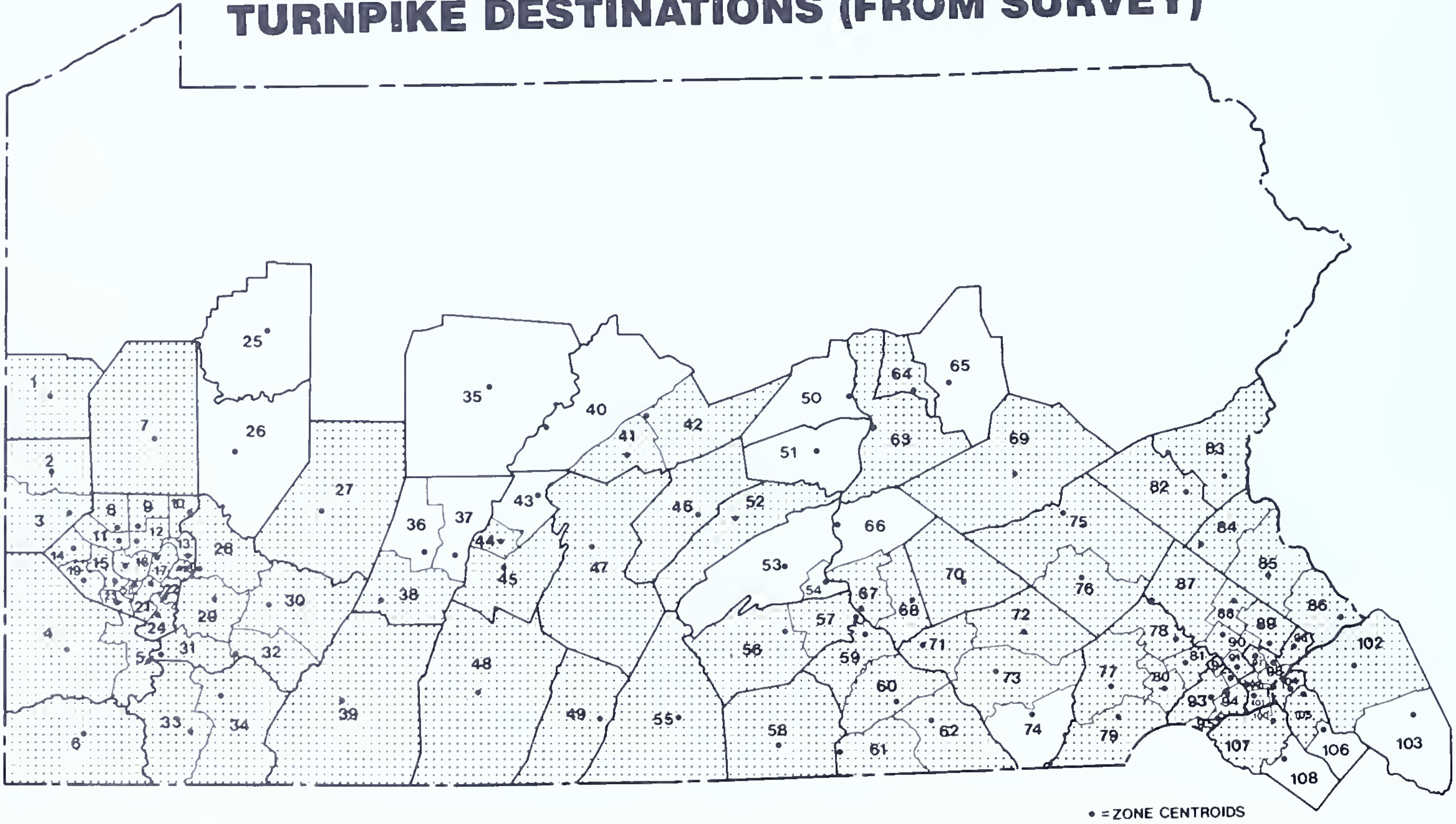


FIGURE 21
STUDY AREA & ASSOCIATED ZONES TURNPIKE ORIGINS (FROM SURVEY)



• = ZONE CENTROIDS

STUDY AREA & ASSOCIATED ZONES TURNPIKE DESTINATIONS (FROM SURVEY)



• = ZONE CENTROIDS

- Current Total Market by Trip Purpose. The information in Table 2 illustrates that the most significant market is the commuter market, with business and "other" trip purposes also being relatively large. The numbers of observed total daily trips by trip purpose and mode were determined by expanding the information collected during the 1985 surveys of rail, turnpike, and air travelers. The numbers of estimated daily trips were obtained from the computer analysis; the differences between observed and estimated trips are considered insignificant. The tourist and school trips represent markets that could be expanded to maximize revenues during the off-peak period. Existing Amtrak rail service provides transportation to all of the markets, the largest being the commuter and business markets. However, the tourist, school and other markets already exist on the present rail transportation system and, conceivably, ridership could be expanded to these special categories by advertising and promoting the rail service.

TABLE 2

Daily Trips by Trip Purpose

(Year 1985)

Mode	Commuter	Business	Tourist	School	Other	Total
Air (est)	950	1,490	240	40	30	2,750
(obs)	960	1,520	210	60	10	2,760
Bus (est)	730	630	220	250	3,080	4,910
(obs)	750	610	240	260	3,110	4,970
Rail (est)	1,880	600	200	170	280	3,130
(obs)	1,890	570	200	160	270	3,090
Auto (est)	937,000	172,910	83,590	31,720	189,320	1,414,540
(obs)	937,900	173,170	83,690	31,700	189,490	1,415,950
Total (est)	940,560	175,630	84,250	32,180	192,710	1,425,330
(obs)	941,500	175,870	84,340	32,180	192,880	1,426,770

The numbers of daily person-trips by trip purpose for the years 1985 and 2000 are shown in Table 3 and it can be observed that the greatest increase is expected in the commuter market (11.8% change). The business market is expected to increase by about 9% to 9.5% by the year 2000. The only difference between the high speed rail and maglev estimates is in the business trip category where it is estimated that the high speed rail system would promote a 9% increase and the maglev system might promote a 9.5% increase in business travel.

TABLE 3

Daily Person-Trips by Trip Purpose

(Years 1985 and 2000)

Trip Purpose	Number of Estimated Trips on All Modes				
	1985	2000 T	Percent Change	2000 M	Percent Change
Commuter	940,560	1,051,400	11.8	1,051,680	11.8
Business	175,630	191,530	9.0	192,340	9.5
Tourist	84,250	85,260	1.2	85,260	1.2
School	32,180	32,650	1.5	32,650	1.5
Other	192,710	196,220	1.8	196,210	1.8
Total	1,425,330	1,557,060	9.2	1,558,140	9.3

Legend

T - High Speed Rail (Steel Wheel)
M - Maglev

o Service Attributes, Perceptions/Fashionableness, and Preference Factors. The market research survey provided quantitative information on the importance to travelers of various service and performance characteristics. It also yielded some qualitative information on Pennsylvania travelers' needs and reactions to the concept of high speed rail. This market research survey used focus groups and sampling procedures to obtain reactions to various service attributes and perceptions of the traveler with respect to the different modes.

In general, the most important attributes were schedule reliability, cost, departure frequency, and average speed or travel time. For the commuter trip, the most important attributes were price, schedule reliability, and departure frequency. Weather vulnerability was also important in the modal selection decision. In the case of the commuter, the ticket price, paid out of the commuter's pocket, was the single most important factor. When combined with schedule reliability, these two attributes represented the major reason for selecting one mode over another.

For other types of trips (family vacations, personal business, school trips, etc.), the major decision factors were trip time, price, schedule reliability, and departure frequency.

CALIBRATION

The calibration of the computer model required that the mathematical equations be validated with respect to both trip purpose and trip distance. This three-dimensional calibration required numerous iterations before computer outputs were equivalent to observed values.

The initial trip generation/distribution equations are illustrated in Table 4. The variables evaluated included the labor force, per capita income, employment, area of destination zones, number of families, average family income, population, college enrollment and number of hotel and motel rooms. These variables were statistically evaluated to determine their significance in estimating the different kinds of trips. This analysis resulted in some variables (those shown as underlined) being deleted from the equations in Table 4.

TABLE 4

Initial Trip Generation/Distribution Equations

Commuter Trips

$$T_{Cij} = a[LF_i]^b \underline{[I_i]}^c_1 [E_j]^d \underline{[E_j/A_j]}^e_1 [t_{Cij}]^f [C_{Cij}]^g$$

Business Trips

$$T_{Bij} = a[LF_i]^b \underline{[I_i]}^c_1 [E_j]^d \underline{[E_j/A_j]}^e_1 [t_{Bij}]^f [C_{Bij}]^g$$

School Trips

$$T_{Sij} = a[F_i]^b [Y_i]^c [CA_j]d \; [t_{Sij}]^e [C_{Sij}]^f$$

Tourist Trips

$$T_{Tij} = a\,[P_i]^b [I_i]^c [P_j]^d [E_j]^e [H_j]^f [t_{Tij}]^g [C_{Tij}]^h$$

Other Trips

$$T_{Oij} = a[P_i]^b \underline{[Y_i]}^c_1 \underline{[P_j]}^d_1 [E_j]^e [E_j/A_j]^f [t_{Oij}]^g [C_{Oij}]^h$$

Where: T_{kij} = Home-based trips from origin zone i to destination zone j for purpose k.

t_{kij} = Weighted average travel time between zones i and j for purpose k.

C_{kij} = Weighted average travel cost per person between zones i and j for purpose k.

LF_i = Labor force in origin zone i.

I_i = Per capita income in origin zone i.

E_j = Employment in destination zone j.

A_j = Area of destination zone j in square miles.

F_i = Number of families in origin zone.

Y_i = Average family income in origin zone i.

P_i = Population in origin zone i.

P_j = Population in destination zone j.

CA_j = College attendance in destination zone j.

H_j = Number of hotel and motel rooms in destination zone j.

a, b, c, d, e, f, g, h = coefficients uniquely determined for each trip purpose by regression.

1 -- Variables deleted based upon results of various regression analyses.

The final equations for the trip generation/distribution model coefficients are provided in Table 5. As indicated in this table, the commuter and business trips are primarily dependent upon the origin labor force and destination employment. The tourist trip is primarily dependent upon the destination employment, origin population, destination population, number of destination hotel/motel rooms, and average per capita income. The school trip is primarily dependent upon the number of families at the origin, the destination college enrollment, and the average family income. The other types of trips are primarily dependent upon the destination employment, origin population, and the destination employment density.

TABLE 5

Calibrated Trip Generation/Distribution
Model Coefficients

Variable	Trip Purpose				
	Commuter	Business	Tourist	School	Other
Travel Cost	- 1.500	- 0.217	- 0.808	- 0.788	- 1.434
Travel Time	- 1.000	- 1.200	- 0.050	- 0.010	- 0.050
Origin Labor Force	0.229	0.376			
Destination Employment	0.800	0.500	- 0.100		0.213
Origin Population			0.100		0.125
Origin Number of Families				0.250	
Destination Employment Density					- 0.118
Destination Population			0.100		
Number of Destination Hotel/Motel Rooms			0.100		
Destination College Enrollment				0.080	
Average Per Capita Income			0.100		
Average Family Income				- 0.763	

The trip generation/distribution calibration summary is provided in Table 6 and it can be observed that there are only minimal differences between the observed and estimated values for each of the trip purposes. The ratio of estimated to observed values is approximately 1.0 in all cases.

TABLE 6

Trip Generation/Distribution
Calibration Summary

Trip Purpose	Number of Daily Person-Trips (One Directional) On All Modes			
	Observed	Estimated	Estimated Minus Observed	Estimated Divided By Observed
Commuter	470,750	470,278	- 472	1.00
Business	87,936	87,814	- 122	1.00
Tourist	42,169	42,127	- 42	1.00
School	16,089	16,089	0	1.00
Other	96,441	96,355	- 86	1.00
Total	713,385	712,663	- 722	1.00

*Pennsylvania High Speed Rail Phase 2 Survey 1985
1980 Journey to Work Data, U.S. Census

The modal split model equations are shown in Table 7, and the primary variables are travel cost, travel time, frequency of service, and access time. The annual family income divided by 2,000 working hours per year provides an estimate of the value of the hourly rate, which is different in each of the 108 zones due to different family incomes.

The mode split coefficients (level-of-service variables) initially were obtained from the results of the DUA survey and then modified during calibration. The mode bias coefficients also were initially obtained from analysis of the results of the DUA survey, then modified as the computer program was validated with respect to both distance and trip purpose.

Results of the mode split validation are provided in Table 8, and it can be observed that there are minimal differences between the estimated and observed values with respect to trip purpose and mode of travel. The total estimated numbers of trips by each mode (air, bus, rail and auto) are essentially equivalent to the observed values, although there are some slight variations by trip purpose.

The computer model also had to be calibrated with respect to trip length and the results are provided in Figures 22 through 26.

The difference between the number of commuter trips obtained from the survey and those estimated by the computer program is shown in Figure 22 and it can be observed that the differences are minimal.

The trip length distribution for business trips is provided in Figure 23. With the exception of some of the shorter distance trips of approximately 50

TABLE 7

Modal Split Model Equations

$$P_c = \frac{e^{U_c}}{\sum e^{U_i}}$$

Where: P_c = Probability of choosing mode c

e = Base of natural logarithms

U_i = Utility or relative value of mode i

$$U_i = aC_i + bYT_i + \frac{cY}{2F_i} + dYA_i + MB_i$$

Where: C_i = Cost of mode i, in dollars

T_i = Travel time in mode i, in hours

F_i = Frequency of mode i (average number of departures per hour)

A_i = Access of mode i (miles to common carrier terminal)

$Y = \frac{\text{Annual family income in dollars}}{\text{2,000 working hours per day}}$

MB = Mode Bias Coefficient

Mode Split Coefficient (Level-of-Service Variables)

Constant	Trip Purpose				
	Commuter	Business	Tourist	School	Other
a	- .0303	- .0202	- .0313	- .0313	- .0313
b	- .0163	- .0163	- .0048	- .0144	- .0144
c	- .0438	- .0244	- .0006	- .0145	- .0019
d	- .0013	- .0006	- .0026	- .0065	- .0026

Mode Bias Coefficients

Mode	Trip Purpose				
	Commuter	Business	Tourist	School	Other
Air	- 5.978 $+ .392*D^{.5}$	- 6.402 $+ .352*D^{.5}$	- 3.178 $+ .190*D^{.5}$	- .400 $+ .060*D^{.5}$	- 5.262 $+ .140*D^{.5}$
Bus	- 2.707 $+ .005*D^{.5}$	- 3.031 $+ .005*D^{.5}$	- 2.740 $+ .005*D^{.5}$	- .050 $+ .085*D^{.5}$	- .100 $+ .010*D^{.5}$
Rail	- 6.283 $+ .377*D^{.5}$	- 6.667 $+ .300*D^{.5}$	- 5.543 $+ .190*D^{.5}$	- 1.000 $+ .060*D^{.5}$	- 5.576 $+ .190*D^{.5}$

Where: D = Distance in miles

TABLE 8

Mode Split Model Validation Summary

Mode	Trip Purpose	Number of 1985 Daily Person-Trips			
		Estimated	Observed*	Estimated Minus Observed	Estimated Divided By Observed
Air	Commuter	948	957	- 9	0.99
	Business	1,488	1,518	- 30	0.98
	Tourist	236	214	22	1.10
	School	40	58	- 18	0.69
	Other	34	14	20	2.43
	Total	2,746	2,761	- 15	0.99
Bus**	Commuter	730	750	- 20	0.97
	Business	630	616	14	1.02
	Tourist	222	240	- 18	0.92
	School	250	258	- 8	0.97
	Other	3,082	3,106	- 24	0.99
	Total	4,914	4,970	- 56	0.99
Rail	Commuter	1,882	1,894	- 12	0.99
	Business	596	568	28	1.05
	Tourist	202	198	4	1.02
	School	168	158	10	1.06
	Other	280	270	10	1.04
	Total	3,128	3,088	40	1.01
Auto	Commuter	936,966	937,899	- 923	1.00
	Business	172,914	173,170	- 256	1.00
	Tourist	83,594	83,686	- 92	1.00
	School	31,720	31,704	16	1.00
	Other	189,312	189,478	- 166	1.00
	Total	1,414,506	1,415,937	- 1431	1.00

*Pennsylvania High Speed Rail Study - Phase 2 Survey 1985
1980 Journey to Work Data, U.S. Census

**Because the 1985 survey included only rail, turnpike and air responses, bus trip estimates obtained in the Phase 1 research were used during Phase 2.

TRIP LENGTH DISTRIBUTION (1985)

FIGURE 22

COMMUTER TRIPS OBSERVED VS. ESTIMATED

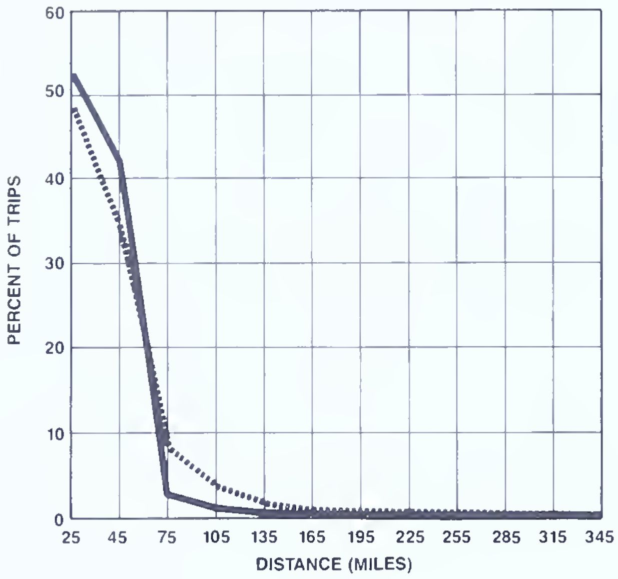


FIGURE 23

BUSINESS TRIPS OBSERVED VS. ESTIMATED

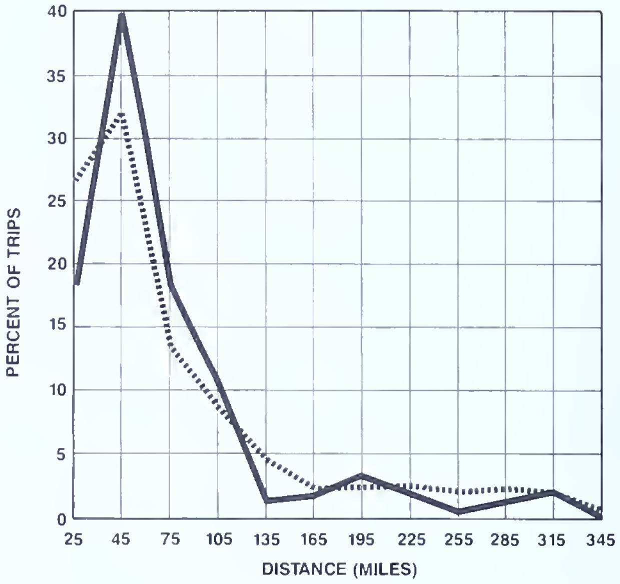


FIGURE 24

SCHOOL TRIPS OBSERVED VS. ESTIMATED

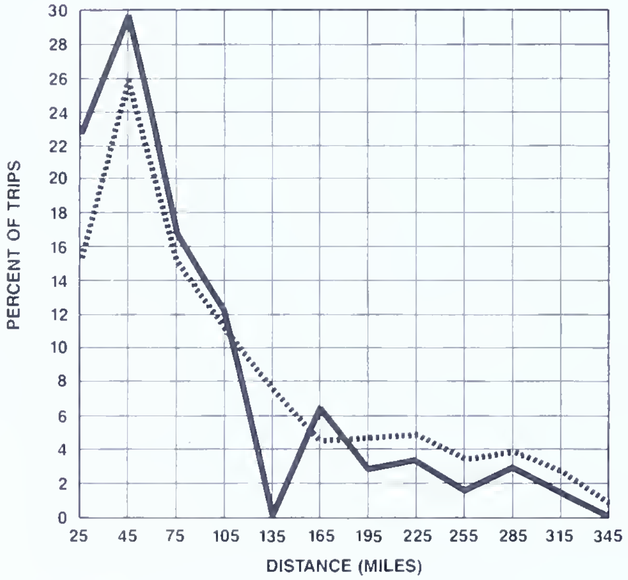


FIGURE 25

TOURIST TRIPS OBSERVED VS. ESTIMATED

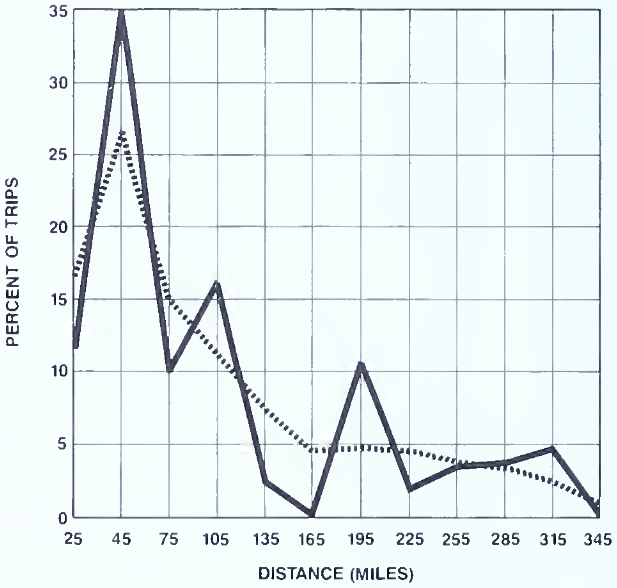
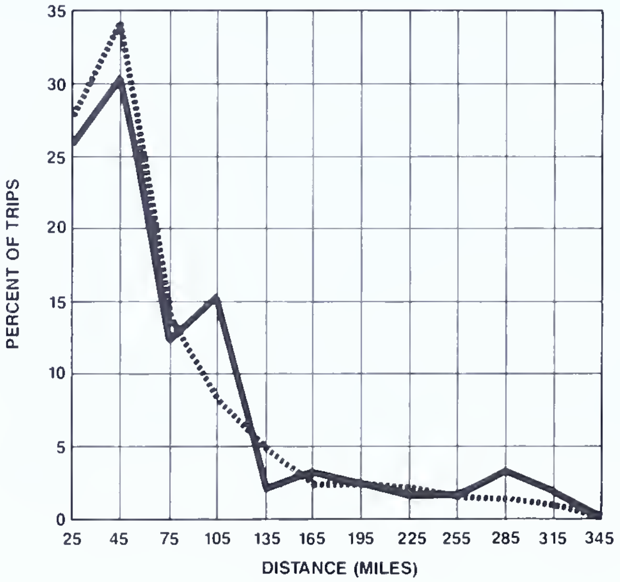


FIGURE 26

OTHER TRIPS OBSERVED VS. ESTIMATED



LEGEND

▬ OBSERVED TRIPS

┅ ESTIMATED TRIPS

miles, there is little difference between the observed values from the surveys and those estimated by the computer program.

Trip length distribution for tourist trips is provided in Figure 24 and the differences between observed values from the surveys and those estimated by the computer are of interest. In general, it can be assumed that most of the difference is due to the fact that tourist trips are not as well understood as commute and business trips and therefore more difficult to estimate. However, since the number of tourist trips is a relatively small percentage of the total number of trips, the differences shown in Figure 20 were not determined to be significant.

The trip length distribution for school trips is provided in Figure 25 and reasonable correlation between the school trips observed from the surveys and those estimated by the computer program was obtained. Although there are minor variations, some of this difference may be due to the fact that a relatively small number of school trips were obtained from the turnpike, air, and rail surveys. However, trip length correlation is considered to be reasonable for this analysis.

The trip length distribution for "other" trips is provided in Figure 26, and it can be observed that reasonable correlation was obtained between observed and estimated trips. Although there were some minor variations, they were not considered significant for this analysis.

In conclusion, the calibration of both models is considered to be excellent.

SENSITIVITY TESTING

Sensitivity tests were conducted to determine how the forecasts might change with changes in the key variables. As previously indicated, the key variables for the trip generation/distribution computer model include cost, travel time and various socioeconomic variables such as the labor force, employment, per capita income, population, family income, college enrollment, and employment density. The modal split model variables primarily include cost, travel time, frequency of service and access time.

Although it was considered desirable to select a "pessimistic" and "optimistic" estimate for each of the variables, it was decided instead to create two scenarios to assist in defining the possible range for the market forecast. The first scenario assumes a no-growth situation from 1980 to the year 2000 as previously discussed. The second scenario assumes that the growth of all variables will continue as projected. The primary reason for selecting these two scenarios is that they may reduce the potential controversy in the projection. Although somewhat conservative, these two scenarios do provide a reasonable understanding of the possible range in the market demand forecasts.

The results of this sensitivity analysis are discussed in the following sections of this report:

- o Trip Generation/Distribution Models. The cost sensitivity analysis is provided in Figure 27, and it can be observed that the commuter and "other" trips are most sensitive to travel costs. The business trip is not sensitive to the travel cost, possibly because of the fact that most business trips are paid for by someone other than the traveler. As indicated in the figure, a 75% reduction in commuter and other fares might result in an increase of 52% to 55% for the initial estimates of rail market demand; a fare increase of 25% could result in a decrease of almost 30% in the base ridership estimate. On the other hand, a decrease in fares for the business traveler would increase the number of business trips by only 5%, and a 25% increase in rail fares would likewise bring a decrease in ridership of only about 5%. The tourist and school trip sensitivity to fare changes was less than for the commuter and "other" trip but more than for the business traveler. As a result of this analysis, it can be assumed that the number of commuter and "other" trips could be increased by offering 10- or 20-trip reduced fare multiple-ride commutation tickets, as is done on most commuter rail lines. The standard fare for business trips could be increased slightly in order to optimize total revenues while only decreasing the volume of business travel. It can also be concluded that special tourist and school package fares could be used to increase rail ridership by more than 20% above that indicated for the base case.

The time sensitivity analysis in Figure 28 indicates that business and commuter trips are extremely sensitive to reductions in travel time. Reducing travel time to 35% of the present rail travel time between Philadelphia and Pittsburgh could bring a ridership increase of 250% to 350% over that observed at present. Since both the high speed rail and

FIGURE 27

COST SENSITIVITY ANALYSIS

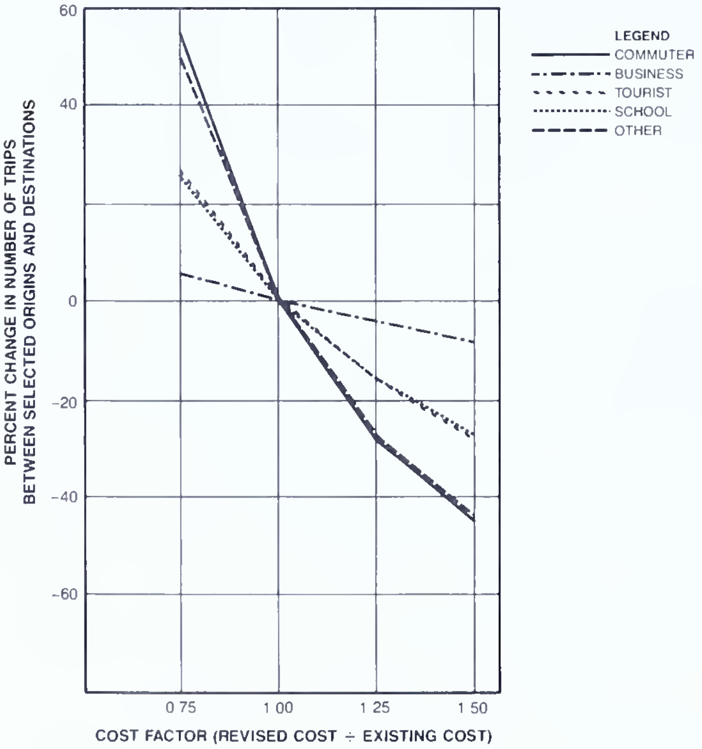
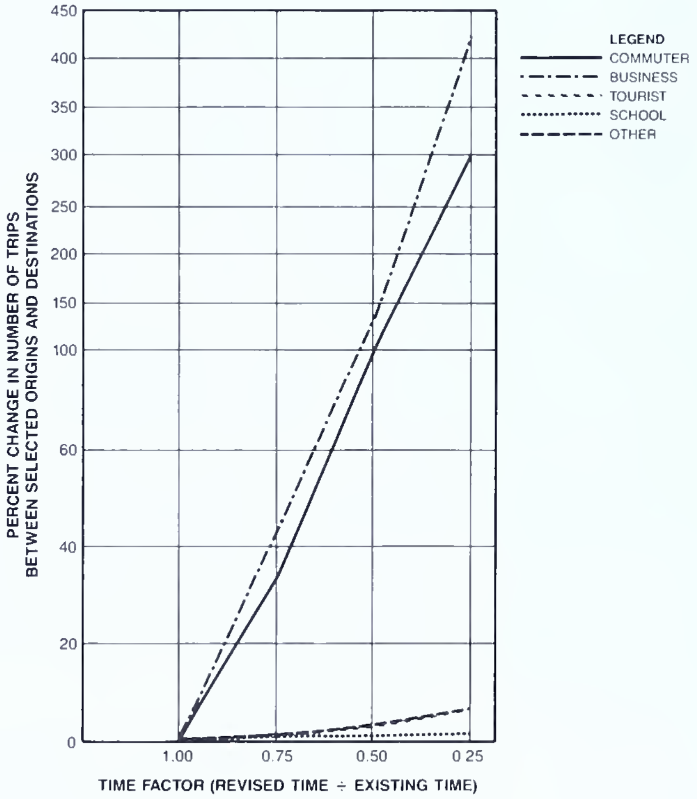


FIGURE 28

TIME SENSITIVITY ANALYSIS



maglev alternatives have reduced this travel time to between 25% and 35% of the existing rail travel time, relatively large increases in both business and commuter travel could be expected. On the other hand, decreasing the travel time, by itself, would have little or no effect on tourists, school and "other" travel as shown in the figure.

The primary variables for the commuter trip are the origin labor force and destination employment. The sensitivity analysis on these two variables is provided in Figures 29 and 30. In Figure 29, it can be observed that a decrease of the year 2000 labor force to 90% of that expected would result in a decrease of ridership of slightly more than 2%, while an increase of 20% in the labor force would result in an increase in the number of rail trips of approximately 4%. Since the 1980 labor force was about 90% of the year 2000 labor force projection, it is possible that the number of commuter rail trips might be reduced by between 1.5% and 2% of that estimated (i.e., "no growth scenario"). The destination employment sensitivity analysis in Figure 30 illustrates that commuter trips are more sensitive to employment at the destination than to the origin labor force. For example, if the labor force was reduced to approximately 80% of the year 2000 projection, it would be expected that commuter ridership would be reduced by approximately 8%. On the other hand, if the employment at the destination were increased by 20%, then commuter rail ridership would be expected to increase by as much as 16%.

FIGURE 29
COMMUTER TRIP PURPOSE ORIGIN LABOR FORCE SENSITIVITY ANALYSIS

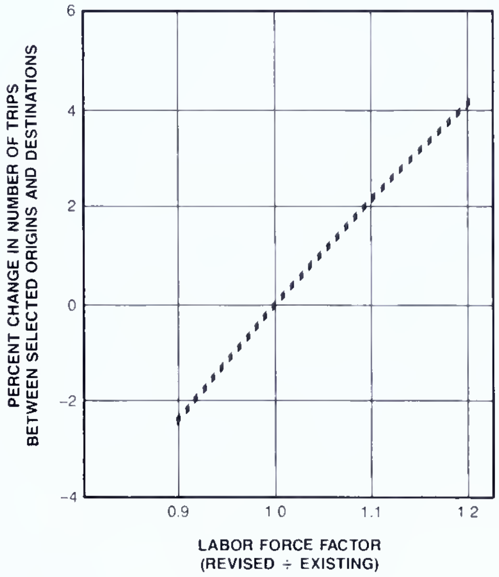
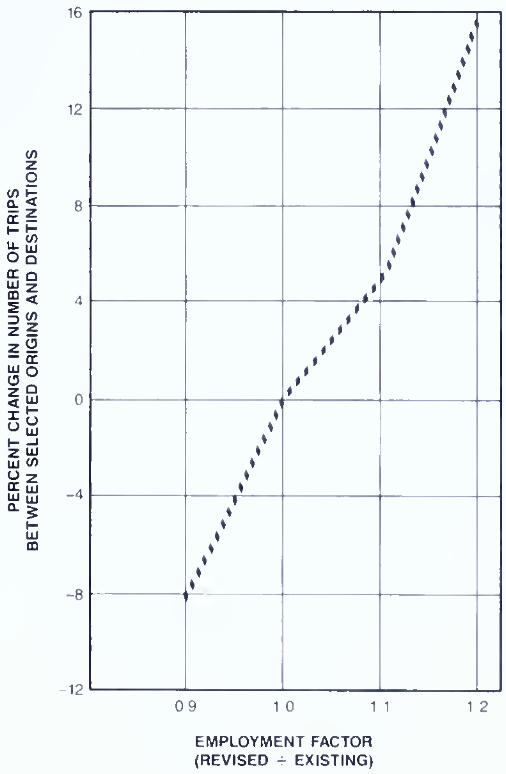


FIGURE 30
COMMUTER TRIP PURPOSE DESTINATION EMPLOYMENT SENSITIVITY ANALYSIS



The primary variables for the business trip are the labor force at the origin and the destination employment. The sensitivity analysis of these two variables is provided in Figures 31 and 32. In Figure 31 it can be observed that the percent change in the number of trips is nearly the same as for the commuter trips. If the year 2000 labor force were decreased by 10% of the expected year 2000 labor force, a reduction of about 4% in the number of business rail trips would be expected. Since it was estimated that the 1980 labor force was about 93% of the estimated year 2000 labor force, the reduction of the number of business rail trips should be about 2½% (i.e., "no growth scenario").

The destination employment sensitivity analysis is shown in Figure 32, and it can be observed that were the destination employment reduced to about 90% of the expected year 2000 employment, a reduction in the number of business rail trips of about 5% would be expected. Also, if the destination employment increased by 10%, then an increase in business rail ridership would be expected of slightly more than 4%. Since the 1980 estimate of employment is approximately 90% of the year 2000 projection, a decrease of 5% of the business rail ridership could be expected (i.e., "no growth scenario").

FIGURE 31

BUSINESS TRIP PURPOSE
ORIGIN LABOR FORCE
SENSITIVITY ANALYSIS

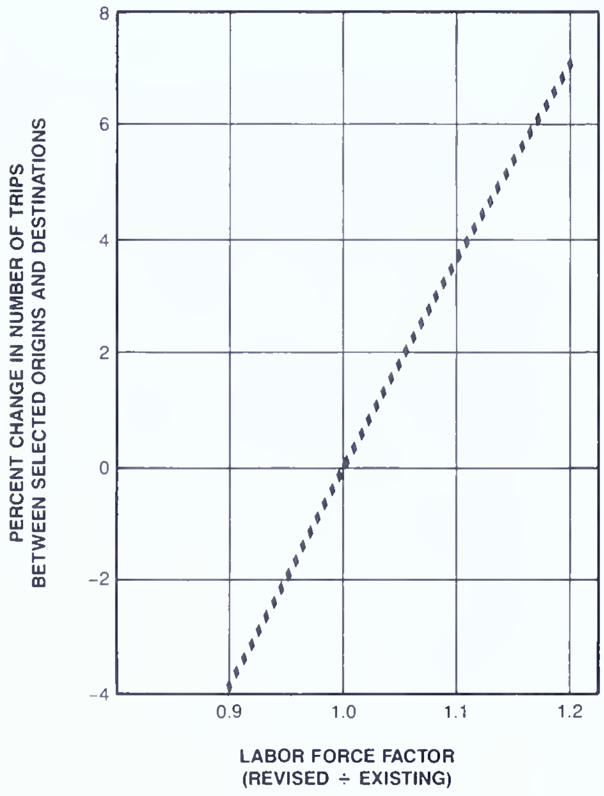
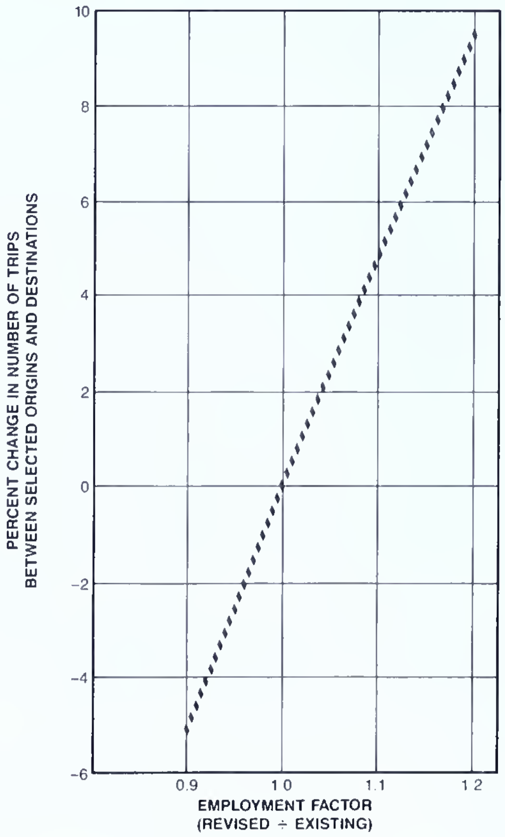


FIGURE 32

BUSINESS TRIP PURPOSE
DESTINATION EMPLOYMENT
SENSITIVITY ANALYSIS



The primary variables in evaluating tourist trips are the origin per capita income and the destination population. The sensitivity analysis on these two variables is provided in Figures 33 and 34. In Figure 33, it can be observed that as per capita income increases, the number of tourist rail riders is expected to decrease. However, were the per capita income to remain near the 1980 level, an increase of about 5% over the tourist rail trip projection could be anticipated.

The sensitivity analysis on the destination population is provided in Figure 34, and it can be observed that were destination population to increase by 25%, an increase in tourist rail ridership of about 2% might be expected. If the population growth is less than anticipated and remains closer to the 1980 level then the estimated year 2000 projection, then a reduction of about 1% in the number of tourist rail trips might be anticipated.

FIGURE 33

TOURIST TRIP PURPOSE ORIGIN PER CAPITA INCOME SENSITIVITY ANALYSIS

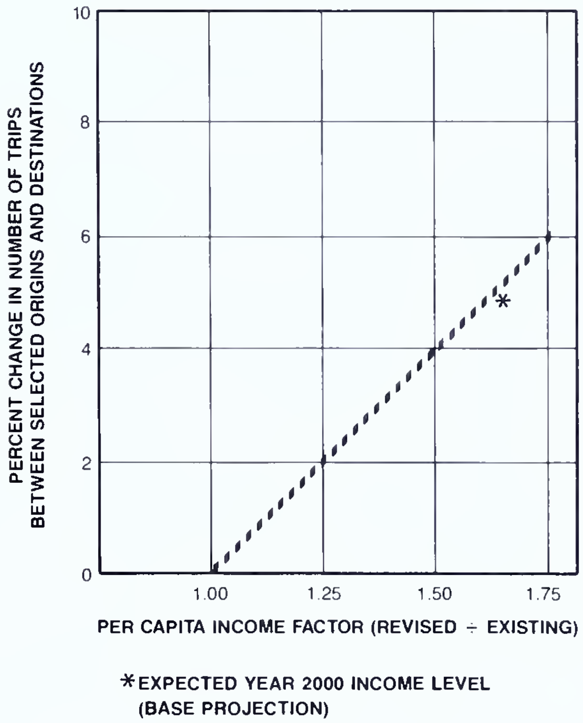
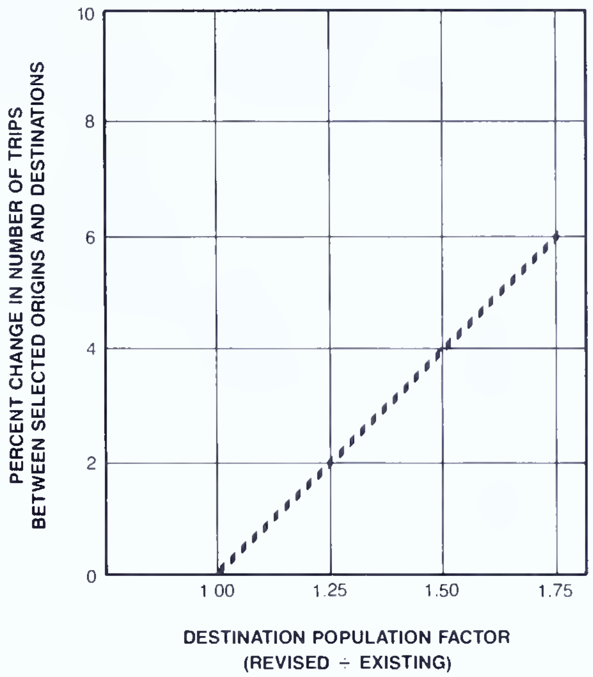


FIGURE 34

TOURIST TRIP PURPOSE DESTINATION POPULATION SENSITIVITY ANALYSIS



The primary variables for the school trip are the origin family income and the destination college enrollment. The sensitivity analysis for these two variables is provided in Figures 35 and 36. In Figure 35, it can be observed that as family income increases, the number of school rail trips is expected to decrease. However, if family income should decrease, it could be anticipated that the number of school rail riders would increase. Were the origin family income to increase by 25% over that projected, then a decrease in the estimated school-trip rail ridership of about 20% might be expected.

The destination college enrollment sensitivity analysis is provided in Figure 36, and it can be observed that minimal change in rail ridership is expected within the probable range of school enrollment. For example, were destination college enrollment to be reduced by 75% over that projected, the decrease in school-trip rail ridership would be less than 1%.

FIGURE 35

SCHOOL TRIP PURPOSE ORIGIN FAMILY INCOME SENSITIVITY ANALYSIS

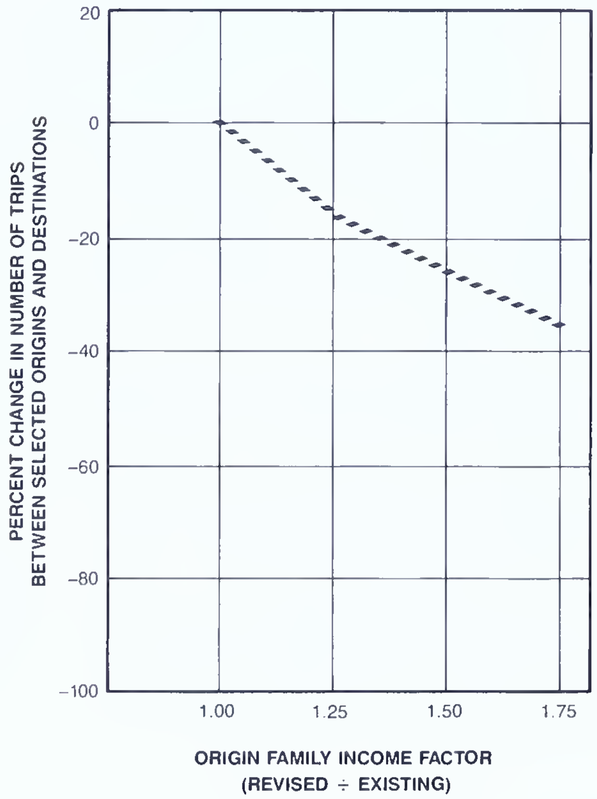
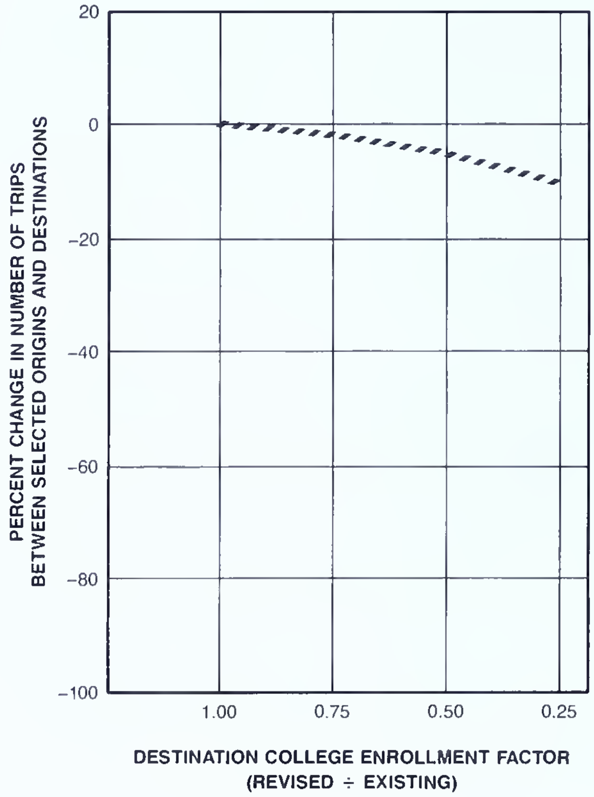


FIGURE 36

SCHOOL TRIP PURPOSE DESTINATION COLLEGE ENROLLMENT SENSITIVITY ANALYSIS



The primary variables for the "other" trip purposes are the destination employment and destination employment density. The sensitivity analysis on these two variables is provided in Figures 37 and 38. In Figure 37, the destination employment sensitivity analysis indicates that an increase of 25% in employment density would result in a decrease of "other"-trip rail ridership of about 5%. However, if 1980 employment were used, expected rail ridership for the "other" trips would be about 2% less than anticipated for the base case. The sensitivity analysis for the destination employment density is provided in Figure 38, and it can be observed that as employment density increases, the number of rail riders is expected to decrease. However, if the projected employment density were closer to the 1980 level than estimated for the year 2000, an increase of less than 2% in "other" rail ridership should be expected.

FIGURE 37

OTHER TRIP PURPOSE DESTINATION EMPLOYMENT SENSITIVITY ANALYSIS

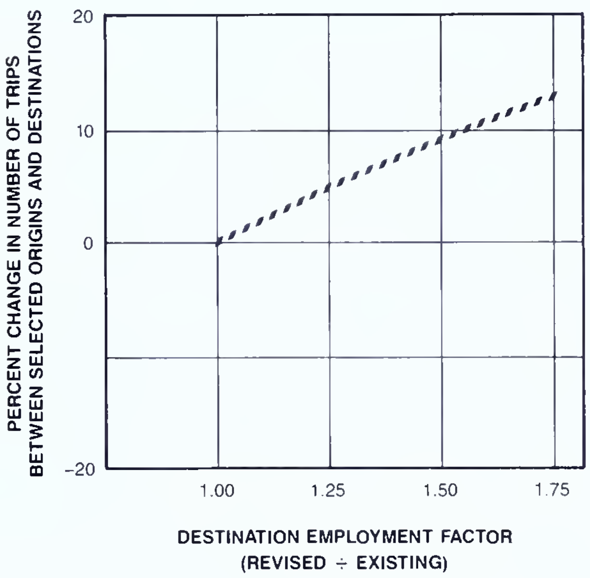
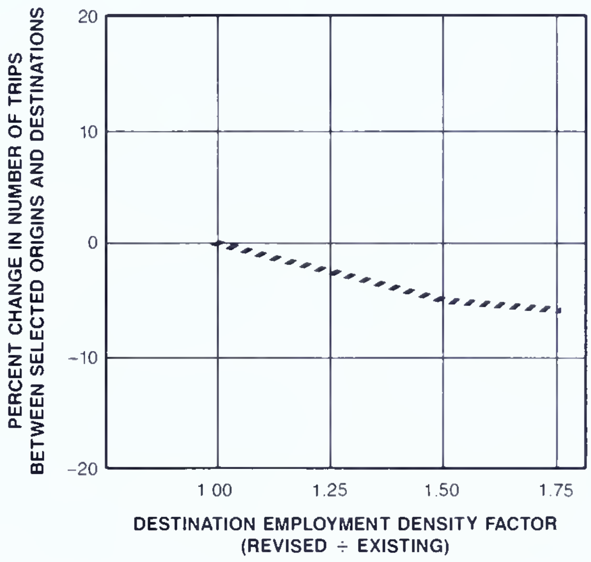


FIGURE 38

OTHER TRIP PURPOSE DESTINATION EMPLOYMENT DENSITY SENSITIVITY ANALYSIS

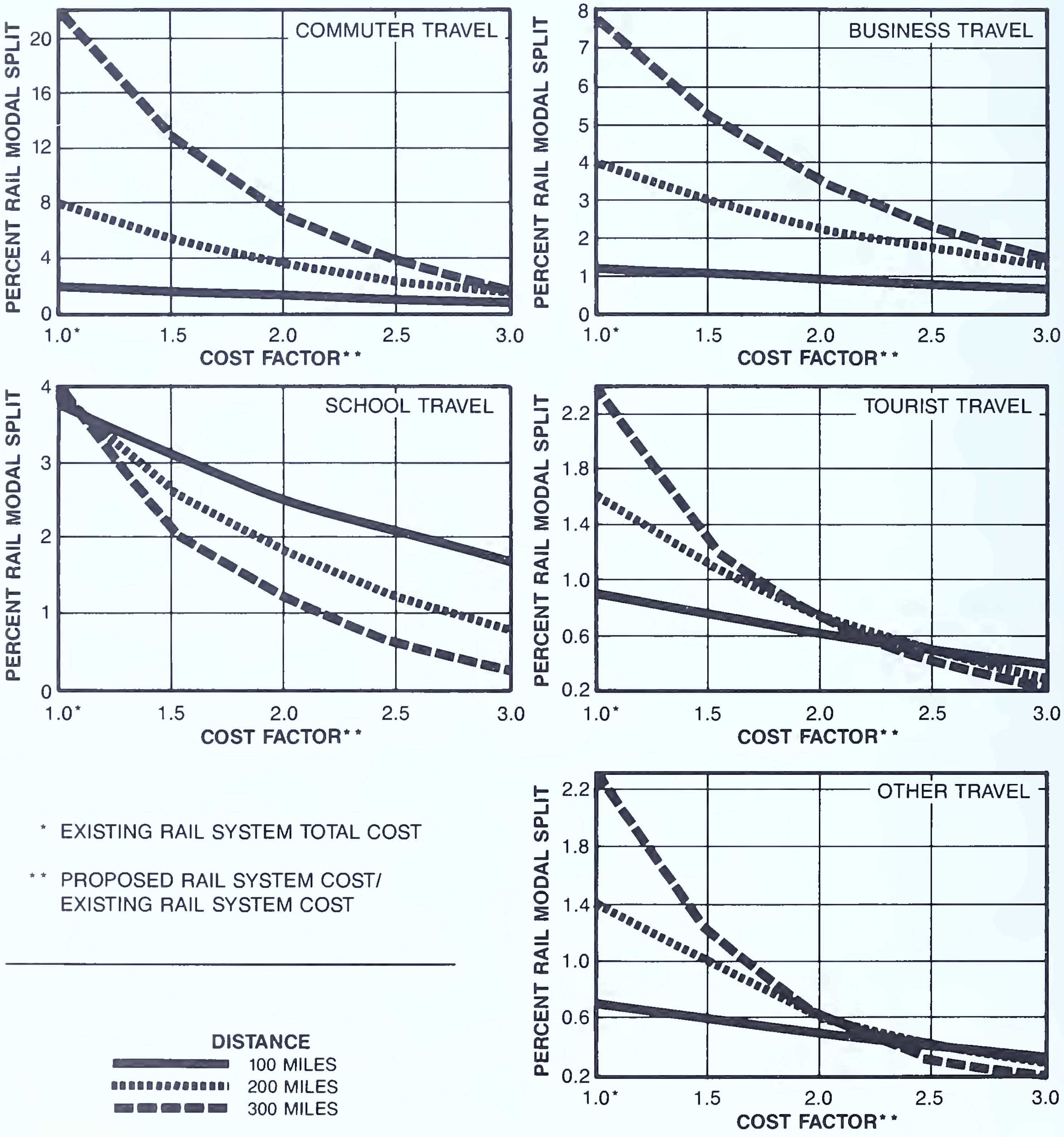


- Modal Split Model Sensitivity Analysis. The primary variables evaluated in the sensitivity analysis of the modal split model include cost, travel time, frequency of service and access time. The sensitivity of these primary variables and the various anticipated changes are provided in Figures 39 to 42.

The modal split model cost sensitivity analysis in Figure 39 illustrates that there are differences in the expected modal split for different types of trips (i.e., commuter, business, school, tourist, and other travel). It also can be observed that the modal split is also sensitive to trip distance, but for distances of less than 100 miles, commuter travel and business travel are essentially insensitive to changes in travel cost. However, for the short trip of less than 100 miles, school travel could be very sensitive to increases in travel

FIGURE 39

MODAL SPLIT MODEL COST SENSITIVITY



* EXISTING RAIL SYSTEM TOTAL COST

** PROPOSED RAIL SYSTEM COST/
EXISTING RAIL SYSTEM COST

cost. The sensitivity analysis also indicates that modal split for tourist and other travel is similar to the sensitivity for commuter and business travel for the different travel distances.

The modal split travel time sensitivity is illustrated in Figure 40, and it can be observed that all travel is sensitive to travel time reductions, especially at longer trip distances. For example, with a reduction in travel time to approximately 30% of existing rail travel time between Pittsburgh and Philadelphia, the percentage choosing rail service could be as high as 30% for commuter travel, 35% for business travel, 30% for school travel, 3% for tourist travel and nearly 20% for other travel.

The modal split model frequency sensitivity is illustrated in Figure 41, and it can also be observed that these different types of trips have different sensitivities to the frequency of service. However, with the exception of school travel, the frequency of service is probably not a major factor in selecting the high speed rail mode, at least within the contemplated frequencies of a train in each direction every 1 to 2 hours.

The modal split model access sensitivity is provided in Figure 42 and it can be observed that as the access time is reduced, the number of people choosing the rail system would be increased slightly in all cases except school travel, which indicates a fairly significant increase. It can also be observed that there are differences in modal split for the different trip lengths regardless of the access travel time.

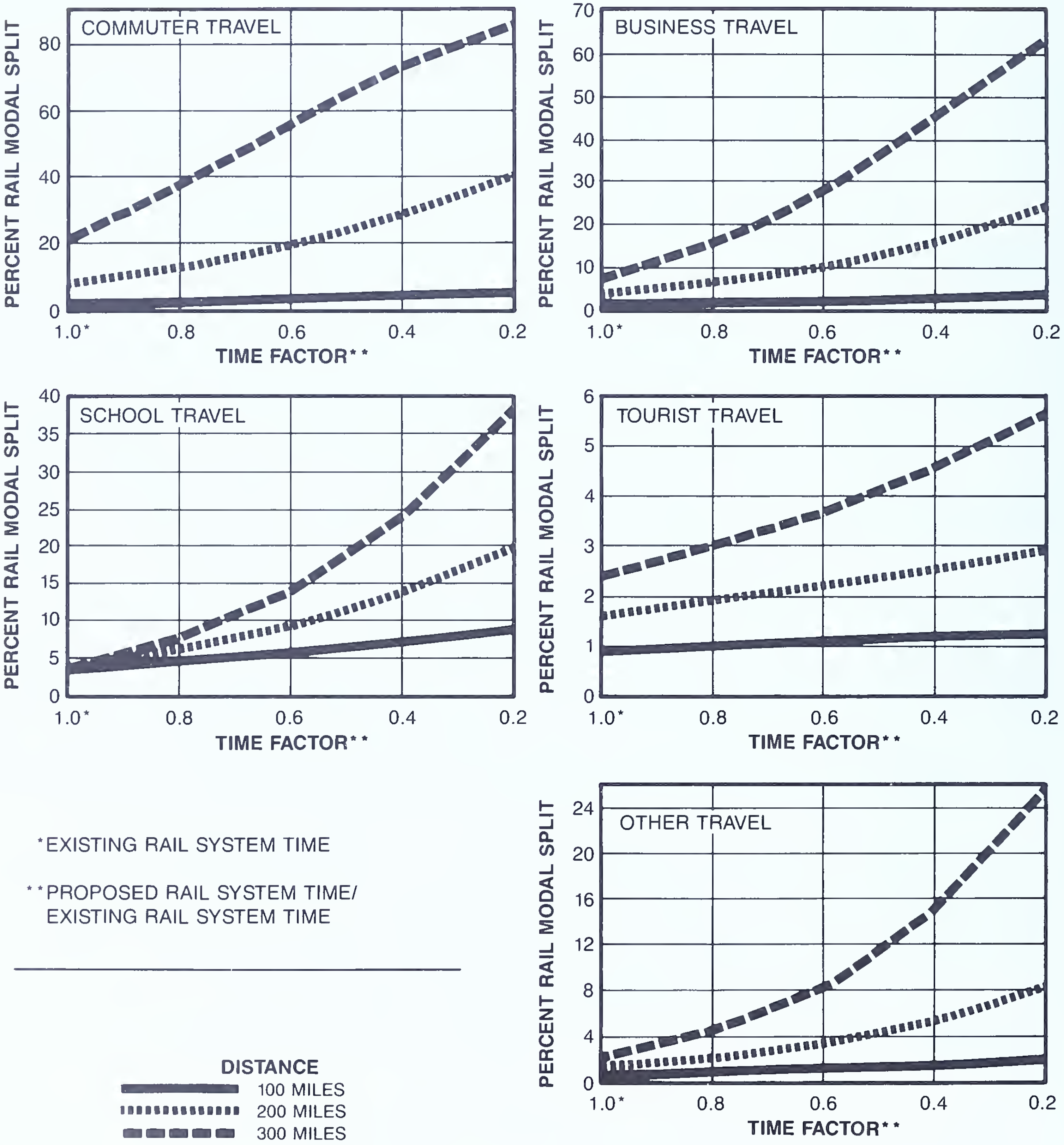
PRESENTATION OF FORECASTS

After completion of the calibration of the computer model and the sensitivity testing, the market demand forecasts were developed. The forecasts were based on proposed hourly service (17 trains per day each way) and cross-state travel times of 2 hours for Maglev trips and 2½ hours for steel wheel/steel rail trips. These market demand forecasts include the total rail, air, bus and automobile ridership; market demand by market segments; station-by-station boardings; peak and off-peak rail ridership; induced trips; and additional considerations such as potential mid-state developments and Atlantic City travel and finally, projections from the year 2000 to the year 2010.

The daily rail station-to-station trip table showing numbers of estimated internal person-trips for the year 2000 is provided in Table 9. This information reflects both the high speed rail market demand estimates and the maglev alternative demand estimates. The computer output provides estimates for each origin and destination, and it can be observed that the greatest number of origins and destinations are expected at the Pittsburgh high speed rail station with only slightly fewer at the Philadelphia station. High ridership is also estimated for the Great Valley/Paoli station. The lowest number of origins and destinations is expected at the Johnstown station.

The information in Table 9 identifies only trips with both origins and destination zones within the study area. These trips were estimated directly from the calibrated computer model.

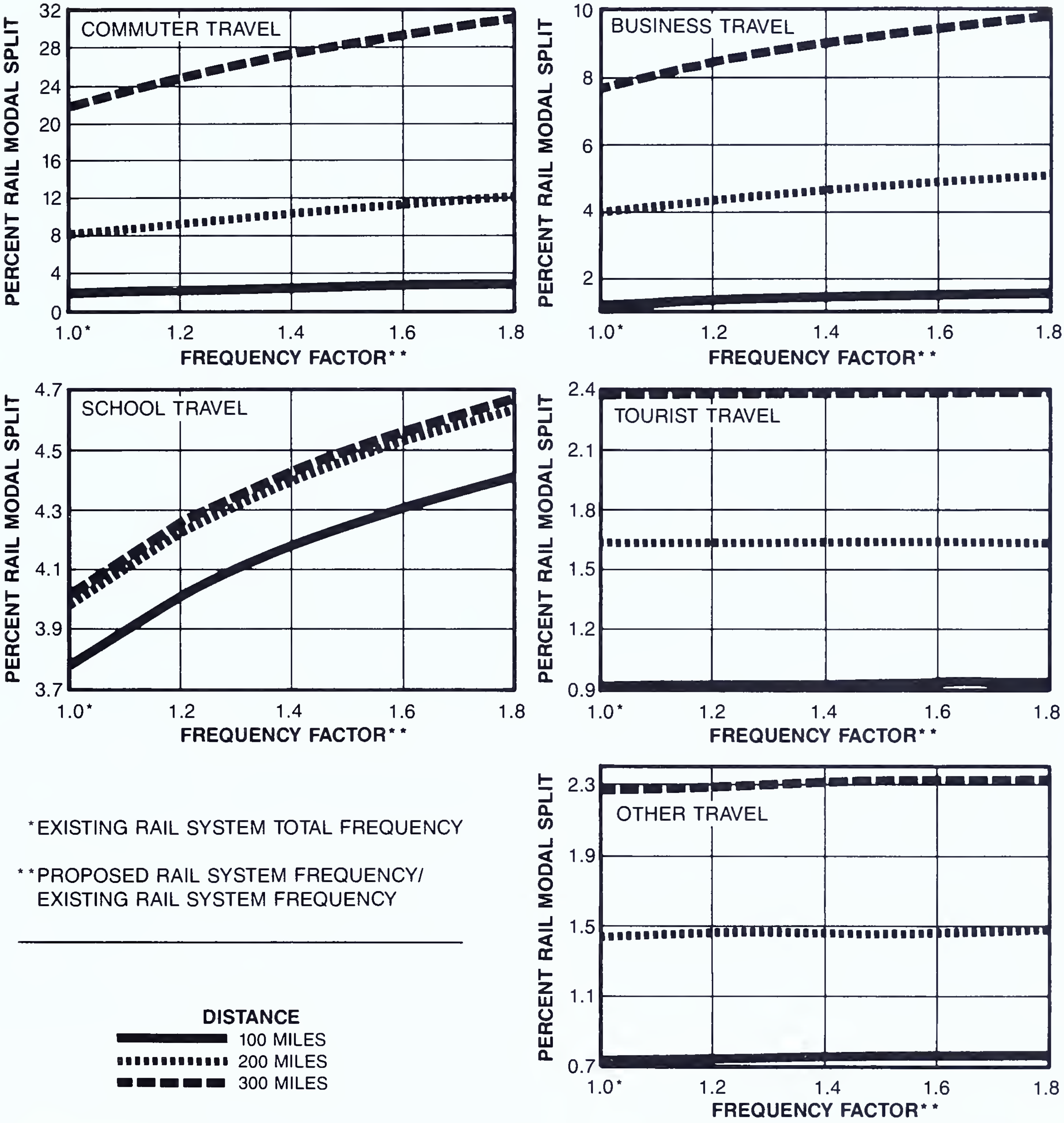
FIGURE 40
MODAL SPLIT MODEL TIME SENSITIVITY



*EXISTING RAIL SYSTEM TIME

**PROPOSED RAIL SYSTEM TIME/
EXISTING RAIL SYSTEM TIME

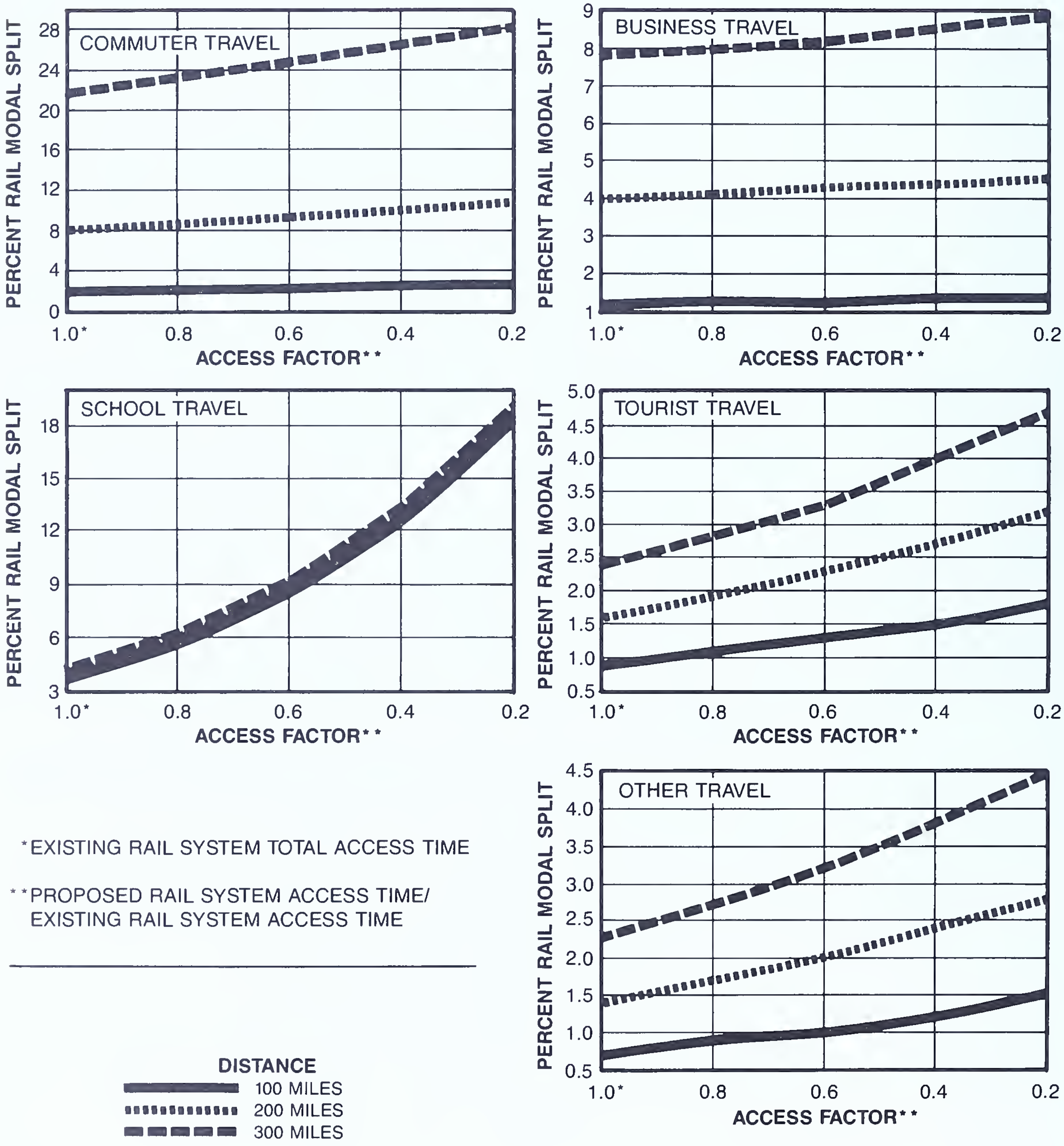
FIGURE 41
MODAL SPLIT MODEL FREQUENCY SENSITIVITY



*EXISTING RAIL SYSTEM TOTAL FREQUENCY

**PROPOSED RAIL SYSTEM FREQUENCY/
EXISTING RAIL SYSTEM FREQUENCY

FIGURE 42
MODAL SPLIT MODEL ACCESS SENSITIVITY



*EXISTING RAIL SYSTEM TOTAL ACCESS TIME

**PROPOSED RAIL SYSTEM ACCESS TIME/
EXISTING RAIL SYSTEM ACCESS TIME

TABLE 9

Daily (Weekday) Rail Station-to-Station Trip Table
Estimated Internal Person-Trips (Year 2000)

High Speed Rail Alternative

	DESTINATION									
ORIGIN	Pittsburgh	Greensburg	Johnstown	Altoona	State College	Harrisburg*	Lancaster*	Great Valley/ Paoli*	Philadelphia*	TOTAL
Pittsburgh	-	370	160	140	170	520	320	720	810	3,210
Greensburg	370	-	70	50	90	220	140	320	380	1,640
Johnstown	160	70	-	30	20	70	40	120	130	640
Altoona	140	50	30	-	50	120	80	180	220	870
State College	170	90	20	50	-	110	60	150	180	830
Harrisburg*	520	220	70	120	110	-	180	270	360	1,850
Lancaster*	320	140	40	80	60	180	-	310	360	1,490
Great Valley/ Paoli*	720	320	120	180	150	270	310	-	290	2,360
Philadelphia*	810	380	130	220	180	360	360	290	-	2,730
TOTAL	3,210	1,640	640	870	830	1,850	1,490	2,360	2,730	15,620

Maglev Alternative

	DESTINATION									
ORIGIN	Pittsburgh	Greensburg	Johnstown	Altoona	State College	Harrisburg*	Lancaster*	Great Valley/ Paoli*	Philadelphia*	TOTAL
Pittsburgh	-	400	160	150	210	610	350	950	1,140	3,970
Greensburg	400	-	80	60	80	210	110	330	430	1,700
Johnstown	160	80	-	30	30	80	40	120	160	700
Altoona	150	60	30	-	60	110	80	190	270	950
State College	210	80	30	60	-	120	60	150	220	930
Harrisburg*	610	210	80	110	120	-	170	290	410	2,000
Lancaster*	350	110	40	80	60	170	-	300	440	1,550
Great Valley/ Paoli*	950	330	120	190	150	290	300	-	360	2,690
Philadelphia*	1,140	430	160	270	220	410	440	360	-	3,430
TOTAL	3,970	1,700	700	950	930	2,000	1,550	2,690	3,430	17,920

*Transfers added to high speed system from local rail service

Although the internal-to-internal trips are recognized as being the major market within Pennsylvania, trips originating outside the area and coming into Pennsylvania or originating in Pennsylvania and terminating elsewhere are also important in developing total market demand estimates. These "external/internal trips" were manually calculated using relationships developed from Amtrak patronage and the results of the 1985 rail, turnpike and air transportation users survey. The Amtrak patronage values summarize Pennsylvania ridership for the month of June 1983, and the information in Table 10 provides a comparison between the results of the 1985 surveys and Amtrak patronage.

TABLE 10

Comparison of Survey Results With Amtrak Ridership

Trip Category		PA HSR Survey of Rail Users (May 1985)		Amtrak Patronage
		Weekday	Weekend Day	June of 1983
Internal	Trips	3,000	648	54,264
	Percent	71.1	37.9	74.9
External/ Internal	Trips	1,106	813	14,990
	Percent	26.2	47.5	20.7
External/ External	Trips	114	250	3,206
	Percent	2.7	14.6	4.4
Total Trips		4,220	1,711	74,460

Since the computer model is structured to provide only estimates of daily internal person-trips, the survey data were used to develop the following relationship for weekend and weekday travel:

$$\frac{\text{Weekday External/Internal}}{\text{Weekday Internal}} = \frac{1,106}{3,000} = .369$$

$$\frac{\text{Weekend External/Internal}}{\text{Weekday Internal}} = \frac{813}{3,000} = .271$$

$$\frac{\text{Weekend Internal}}{\text{Weekday Internal}} = \frac{648}{3,000} = .216$$

These relationships, when applied to the number of weekdays and weekend days for a year, produce estimates of annual ridership. The number of weekdays and weekend days were calculated as follows:

$$\text{Annual Weekdays} = \frac{\text{52 weeks}}{\text{year}} \times \frac{\text{5 weekdays}}{\text{week}} - \text{10 holidays} + \text{1 odd day} = \text{251 weekdays}$$

$$\text{Annual Weekend Days} = \frac{\text{52 weeks}}{\text{year}} \times \frac{\text{2 weekend days}}{\text{week}} + \text{10 holidays} = \text{114 weekend days}$$

This process associates holiday travel with the level of demand normally experienced on weekends. While most holiday travel is less than that on a normal weekday, some holidays such as Thanksgiving have a significant amount of travelers. Overall, the placement of the ten holidays at the weekend day travel levels is both conservative and reasonable.

The annualization calculations were completed by applying the above rates and day types in the following formulas:

- Annual Trips (Internal)

$$\text{AIIT} = 251 \times (\text{WDIT}) + .216 \times (114) \times (\text{WDIT})$$
$$\text{AIIT} = 275.6 \times (\text{WDIT})$$

- Annual Trips (External to Internal)

$$\text{AEIT} = .369 \times 251 \times (\text{WDIT}) + .271 \times (114) \times \text{WDIT})$$
$$\text{AEIT} = 123.5 \times (\text{WDIT})$$

- Annual Total Trips

$$\begin{aligned} \text{Total Trips} &= \text{AIIT} + \text{AEIT} \\ &= 275.6\ (\text{WDIT}) + 123.5\ (\text{WDIT}) \\ &= 400 \times (\text{WDIT}) \end{aligned}$$

where:
WDIT = weekday internal trips (estimated by the model)
AIIT = annual internal trips, weekday and weekend day
AEIT = annual external/internal trips, weekday and weekend day

The estimated numbers of total daily person-trips are provided in Table 11 and indicate both the internal-to-internal as well as external-to-internal and vice versa high speed rail and maglev trips. It can be observed from this data that with regard to total trips, Philadelphia is expected to have the highest number of origins and destinations, with Pittsburgh second and Paoli third. In addition to providing initial insight into station-to-station travel, the information in Table 11 also provides some insight into total station activity.

TABLE 11

Daily (Weekday) Rail Station-to-Station Trip Table
Estimated Total Person-Trips (Year 2000)

High Speed Rail Alternative

	DESTINATION									
ORIGIN	Pittsburgh	Greensburg	Johnstown	Altoona	State College	Harrisburg*	Lancaster*	Great Valley/ Paoli*	Philadelphia*	TOTAL
Pittsburgh	-	370	210	210	170	690	410	780	1,450	4,290
Greensburg	370	-	70	50	90	220	140	320	380	1,640**
Johnstown	210	70	-	30	20	70	40	120	190	750
Altoona	210	50	30	-	50	120	80	180	300	1,020
State College	170	90	20	50	-	110	60	150	180	830**
Harrisburg*	690	220	70	120	110	-	180	270	800	2,460
Lancaster*	410	140	40	80	60	180	-	310	930	2,150
Great Valley/ Paoli*	780	320	120	180	150	270	310	-	940	3,070
Philadelphia*	1,450	380	190	300	180	800	930	940	-	5,170
TOTAL	4,290	1,640**	750	1,020	830**	2,460	2,150	3,070	5,170	21,380

Maglev Alternative

	DESTINATION									
ORIGIN	Pittsburgh	Greensburg	Johnstown	Altoona	State College	Harrisburg*	Lancaster*	Great Valley/ Paoli*	Philadelphia*	TOTAL
Pittsburgh	-	400	220	240	210	810	450	1,020	1,870	5,220
Greensburg	400	-	80	60	80	210	110	330	430	1,700**
Johnstown	220	80	-	30	30	80	40	120	230	830
Altoona	240	60	30	-	60	110	80	190	360	1,130
State College	210	80	30	60	-	120	60	150	220	930**
Harrisburg*	810	210	80	110	120	-	170	290	920	2,710
Lancaster*	450	110	40	80	60	170	-	300	1,090	2,300
Great Valley/ Paoli*	1,020	330	120	190	150	290	300	-	1,100	3,500
Philadelphia*	1,870	430	230	360	220	920	1,090	1,100	-	6,220
TOTAL	5,200	1,700**	830	1,130	930**	2,710	2,300	3,500	6,220	24,540

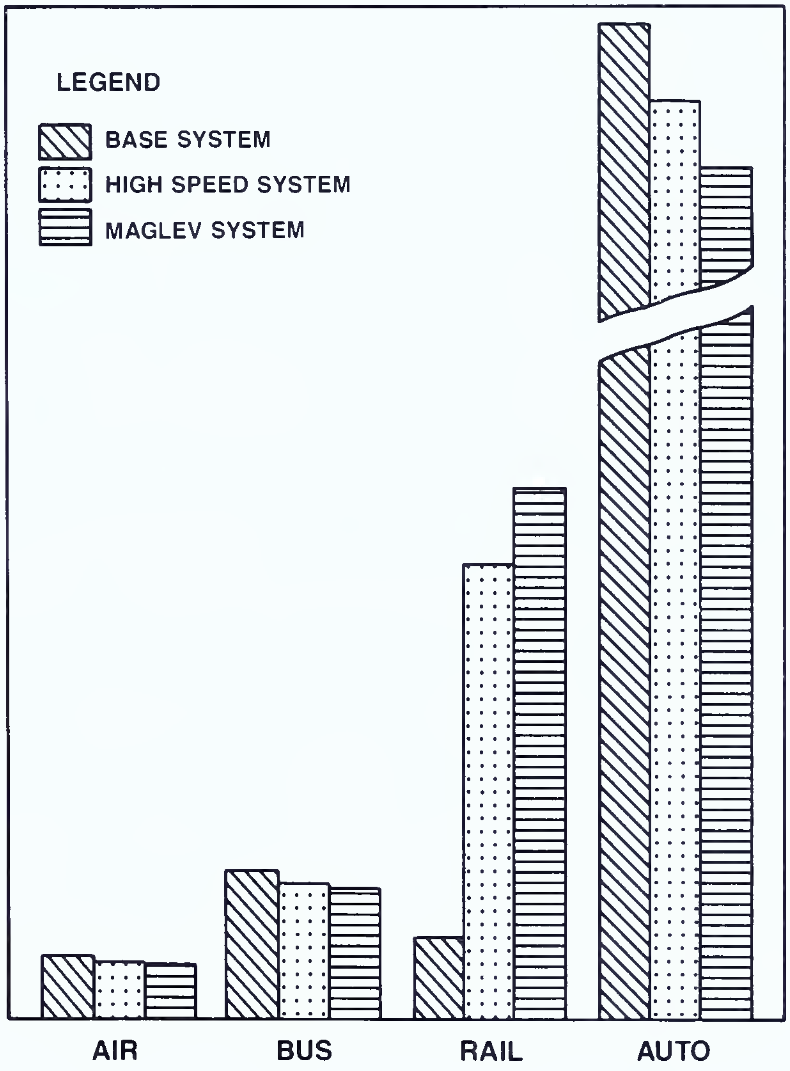
*Transfers added to high speed system from local rail service

**Out-of-state trip calculations for State College and Greensburg are conservatively estimated as identical to those for in-state-only trips because Amtrak data partly were used to determine the number of out-of-state rail connections; Amtrak does not directly serve State College, and no out-of-state trips originating or terminating at Greensburg were recorded among the data Amtrak supplied.

The results of the computer analysis and the forecasts of trips by mode and by market segments are presented in the following paragraphs:

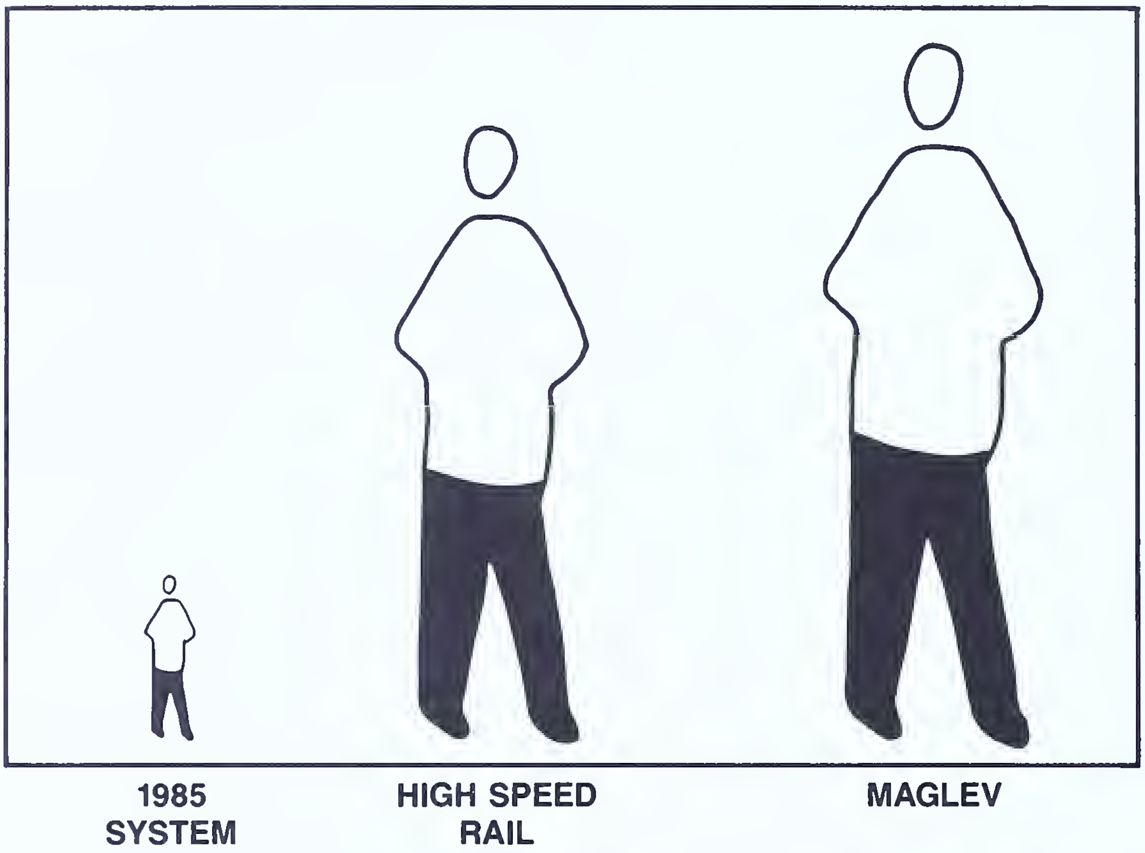
- Total Rail, Air, Bus and Automobile Ridership. The year 2000 daily numbers of trips by mode for each alternative are provided in Figure 43. It can be observed that the maglev system would have its greatest impact on automobile ridership with only a slight impact upon bus and air travel. The high speed rail alternative would also have a reasonable impact on automobile usage and is expected to reduce bus travel by approximately 80 passengers per day and air travel by about 310 per day.

FIGURE 43
YEAR 2000 DAILY TRIPS BY MODE FOR EACH ALTERNATIVE



The volume of rail person-trips by rail type for the year 2000 is also illustrated in Figure 44. It can be observed that a significant increase in rail ridership is expected for either a high speed rail system or a maglev alternative. With 1985 rail system travel times, it is estimated that about 3,390 people would use this rail system daily; this rail ridership increases to approximately 16,660 for a high speed rail system and 18,710 for a maglev alternative.[5]

FIGURE 44
DAILY RAIL PERSON-TRIPS BY RAIL TYPE



o Market Demand by Market Segment. The comparative total daily trip volumes by trip purpose are illustrated in Figure 45, and it can be observed that the dominant market is the commuter trip, with business, tourist, school and other types of trips being significantly smaller. It is estimated that more than 1 million of the daily trips in the year 2000 would be commuter trips with the next largest markets being between 191,000 and 196,000 (business and "other" trips). The tourist trip market is estimated at about 85,260 with the school trip market being approximately 32,700.

The numbers of estimated daily trips by trip purpose are also summarized in Table 12 for the year 2000. It can be observed that the largest rail market should be the commuter market but that a large

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[5] Includes all internal-to-internal rail trips and not just high speed rail and maglev.

FIGURE 45

TOTAL DAILY TRIPS BY TRIP PURPOSE

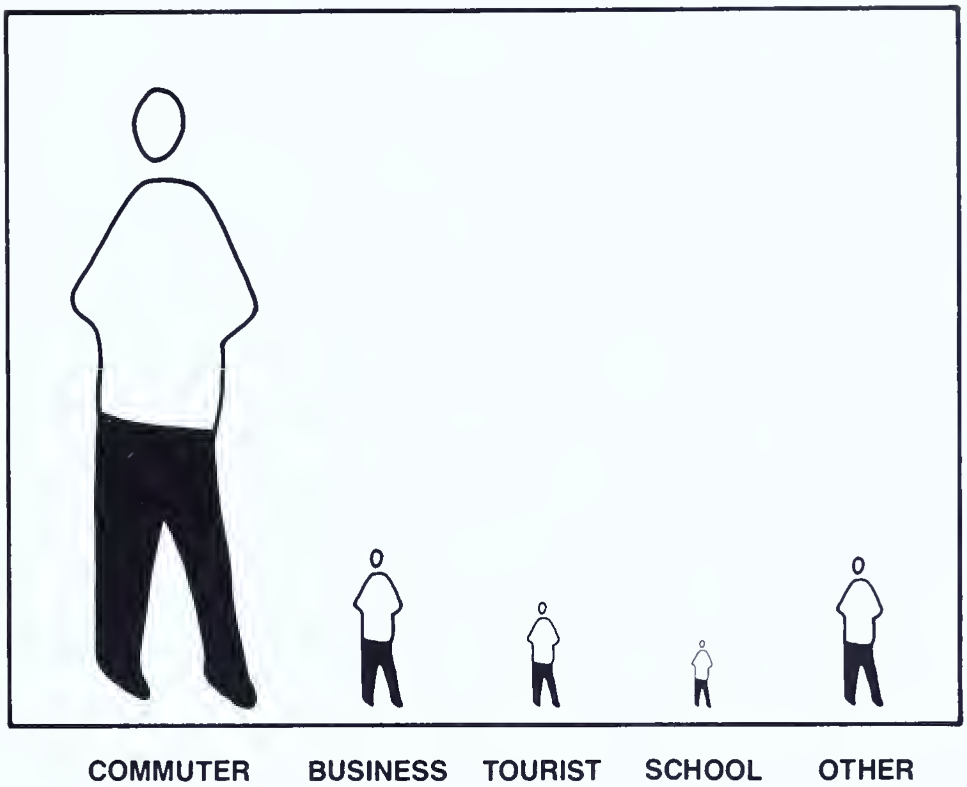


TABLE 12

Number of Estimated Daily Weekday Trips by Trip Purpose and Mode

(Year 2000)

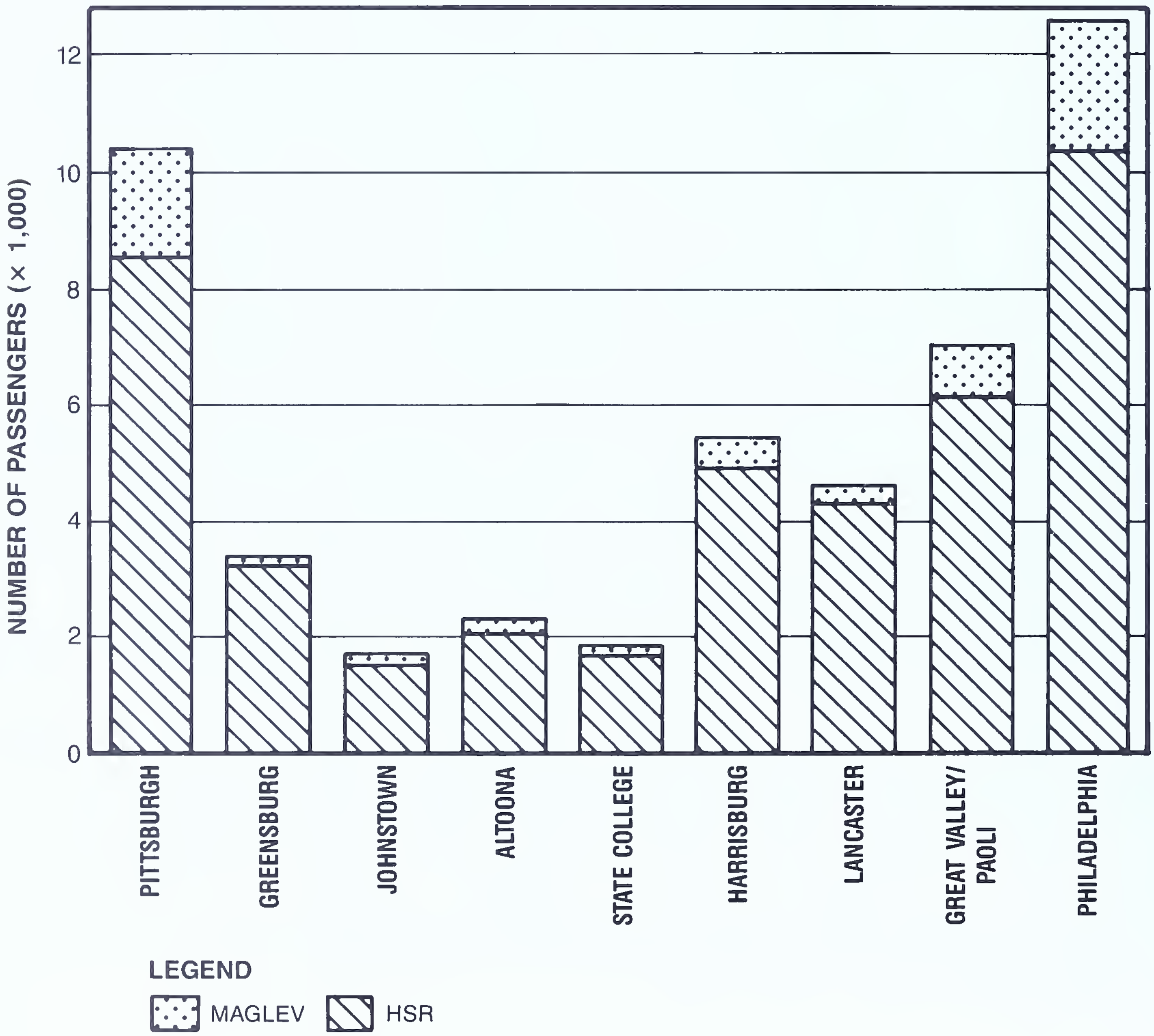
Mode		Commuter	Business	Tourist	School	Other	Total
Air	T	920	1,440	230	40	40	2,670
	M	920	1,440	230	40	30	2,660
Bus	T	780	660	220	230	3,110	5,000
	M	780	660	210	230	3,110	4,990
Rail	T	9,500	4,630	1,500	470	560	16,660
	M	10,510	5,470	1,580	520	630	18,710
Auto	T	1,040,200	184,800	83,310	31,910	192,510	1,532,730
	M	1,039,470	184,770	83,240	31,860	192,440	1,531,780
Total	T	1,051,400	191,530	85,260	32,650	196,220	1,557,060
	M	1,051,680	192,340	85,260	32,650	196,210	1,558,140

T - High Speed Rail (Steel Wheel)
M - Maglev

number of business and tourist trips are also expected on the rail system. The school and other types of trips are smaller but important segments of the total market demand since they travel at different times than the commuter and their revenues could help to offset operating expenses during the off-peak period.

o Station-by-Station Loadings. The estimated daily (weekday) rail station activity (total arrivals and departures) is provided in Figure 46 for both the high speed rail and maglev alternatives. As shown in this figure, it is estimated that Philadelphia would have the highest station loadings with between 10,340 and 12,440 arrivals and departures per weekday. The Pittsburgh station is anticipated to handle 8,580 and

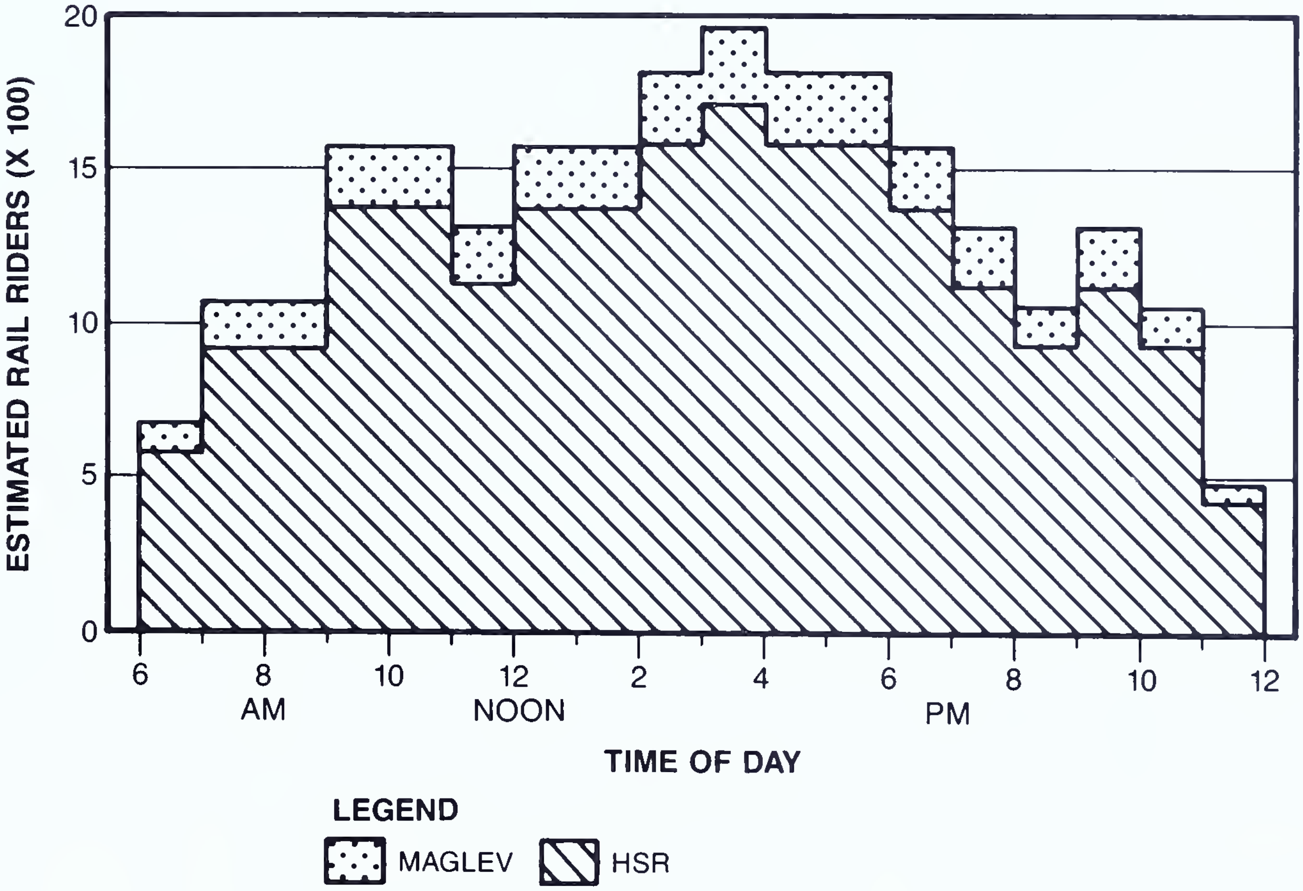
FIGURE 46
ESTIMATED DAILY (WEEKDAY) STATION ACTIVITY (Total Arrivals and Departures)



10,400 riders per weekday, depending upon the technology selected. The Great Valley/Paoli station is also anticipated to have a relatively high rail ridership and it is estimated that between 6,140 and 7,000 people would move through this station every weekday. The lowest ridership is estimated at Johnstown where between 1,500 and 1,660 riders per weekday have been estimated.

- Peak and Off-Peak Rail Ridership. The expected hourly distribution of rail trips is provided in Figure 47. As shown in this figure, it is estimated that the maximum period would be between 3 P.M. and 4 P.M. when between 1,700 and 1,960 rail riders are expected. The lowest expected rail ridership is between 11 P.M. and midnight, when between 400 and 500 rail riders are anticipated. Since the present operational schedule assumes the initiation of hourly high speed rail service at 6:00 A.M. and termination of service at 11:30 P.M. (17 trains per day each way) the information in Figure 47 gives some insight into how the overall transportation service can be balanced to reduce the peak and off-peak ridership differences and provide a more balanced distribution of rail trips. However, further analysis is required on the travel behavior and patterns of the different market segments.

FIGURE 47
EXPECTED HOURLY DISTRIBUTION OF RAIL TRIPS



- Induced Trips. Induced trips are those that did not exist on any mode prior to implementing a new service or transportation facility. Induced trips are therefore not diverted from other modes, but result from a change in trip generation and distribution because of the improved accessibility between locations served by the new transportation service. Induced trips can also result from a change in trip distribution due to a change in the desirability of travel between the locations served with respect to other potential origins and destinations, or because of the increased level of economic activity in the vicinity of stations served by a new transportation service. In order to provide as much insight as possible into this type of trip, the trip generation and distribution computer model was specifically designed to provide information on these characteristics.

  The trip generation/distribution computer model was used to generate travel based on weighted average travel time and travel cost information, as well as on socioeconomic data. Reduction in the weighted average travel time or travel cost will result in the generation of additional trips. From the information in Figure 43 and in Table 12, it can be determined that with the base case system, approximately 1,554,160 total daily trips would be made. The total trip generation with a high speed rail system is 1,557,060 and therefore it can be estimated that approximately 2,900 total trips would be induced by the implementation of a high speed rail service. (It should be noted that these additional trips will be distributed among all modes by the modal split model.) With a maglev alternative, the total number increases to 1,558,140 and the difference between this number of trips and the base case is 3,980 trips; these trips are considered to be induced trips. Although the number of trips is relatively small in comparison to the total number of trips (between .2 and .3%), the percentage of rail riders is expected to increase by between 17% and 21% due to the inducement of travel on all modes caused by a high speed rail service.

- Additional Considerations. In the development of a total market demand estimate for the Pennsylvania high speed rail service, it was assumed that two additional market segments could be obtained.

  The first market segment includes the planned Philadelphia-to-Atlantic City Amtrak service, which would provide transportation for people going to this resort/entertainment complex. The presence of a major tourist-travel generator in the mid-state area would also increase high speed rail ridership, possibly substantially, and was therefore investigated. This mid-state location was selected for study because such a location would cause a possible increase in the number of passenger-miles, and therefore would contribute to total rail revenues. Also, since several mid-state developments have already occurred, the possibility of a major expansion and associated development appeared to be reasonable.

- The Connection With a Philadelphia-to-Atlantic City Rail Service. In 1982, there were approximately 16.2 million trips to the Atlantic City resort/entertainment complex (15 million by automobile, 1 million by bus, and .3 million by air). The New Jersey Department of Transportation estimates a growth rate in the number of these trips of between 2% per year and 4% per year. Applying these growth rates results in a low estimate of 23.3 million trips per year and a high estimate of 33.0 million trips per year by the year 2000.

  The distribution of origins for present trips to Atlantic City was available from a survey conducted by the New Jersey Department of Transportation. A simple linear regression model was developed to predict the distribution of origins for a high speed rail service. Modal split estimates were provided by the modal split model for origins in Pennsylvania, assuming an interconnection in Philadelphia between the proposed Atlantic City rail service and the high speed rail terminal.

  The results of this analysis are shown in Table 13, and it is estimated that, by the year 2000, between 84,000 and 120,000 riders annually would use the high speed rail system for access to Atlantic City service and between 86,000 and 123,000 riders annually would use the maglev system.

TABLE 13

Estimated Additional
Pennsylvania Ridership
Connecting to
Philadelphia-Atlantic
City Rail Service

(Year 2000)

Annual Ridership in Thousands			
HSR System		Maglev System	
Low	High	Low	High
84	120	86	123

- Mid-State Resort Development. A review of the characteristics of 12 major resort complexes was conducted to determine the general requirements for a similar development in the mid-Pennsylvania area and the possible size of the total market. These characteristics included: physical size of each facility; lodging and convention facilities; recreational characteristics, such as the number of ski slopes, golf courses, tennis courts, swimming and fishing facilities; and historic or amusement center attractions. The resort complexes reviewed were: Seven Springs (PA), Hidden Valley (PA), Blue Knob Ski Area (PA), Gettysburg National Military Park (PA), Hersheypark (PA), Snowshoe Ski Area (WVA), Killington Ski Area (VT), Summit Lodge (VT), Americana Great Gorge Resort (NH), Indian Lake Resort (IL), Eagle Ridge Inn and Resort (IL), and Steamboat Springs (CO). Based on this review, the following range of total market potentials was estimated:

- It was estimated that with a complete summer/winter resort complex with recreation, lodging and convention facilities the possible market would be approximately 3 million visitors.
- With all characteristics of the preceding summer/winter resort complex plus a major theme park, museums and historic attractions it was estimated that approximately 7 million visitors would represent the market.
- With all the characteristics of the preceding development plus major entertainment and facilities or some other major novel attraction, it was estimated that approximately 10 million visitors would represent the market.

Information was obtained from a recent survey conducted by the Harrisburg Hershey Area Tourist Promotion Agency on the origins of visitors to Hersheypark. These data were used to specify a simple linear regression model providing the percentage of visitors as a function of population and distance. This linear equation was used to estimate the origins for the hypothetical mid-state resort development and the high speed rail mode split model was then used to estimate rail ridership.

The resulting ridership is provided in Table 14, and it can be observed that with a high speed rail system, between 237,000 and 788,000 people

TABLE 14

Estimated Additional Ridership Resulting From A Hypothetical Mid-State Development

(Year 2000)

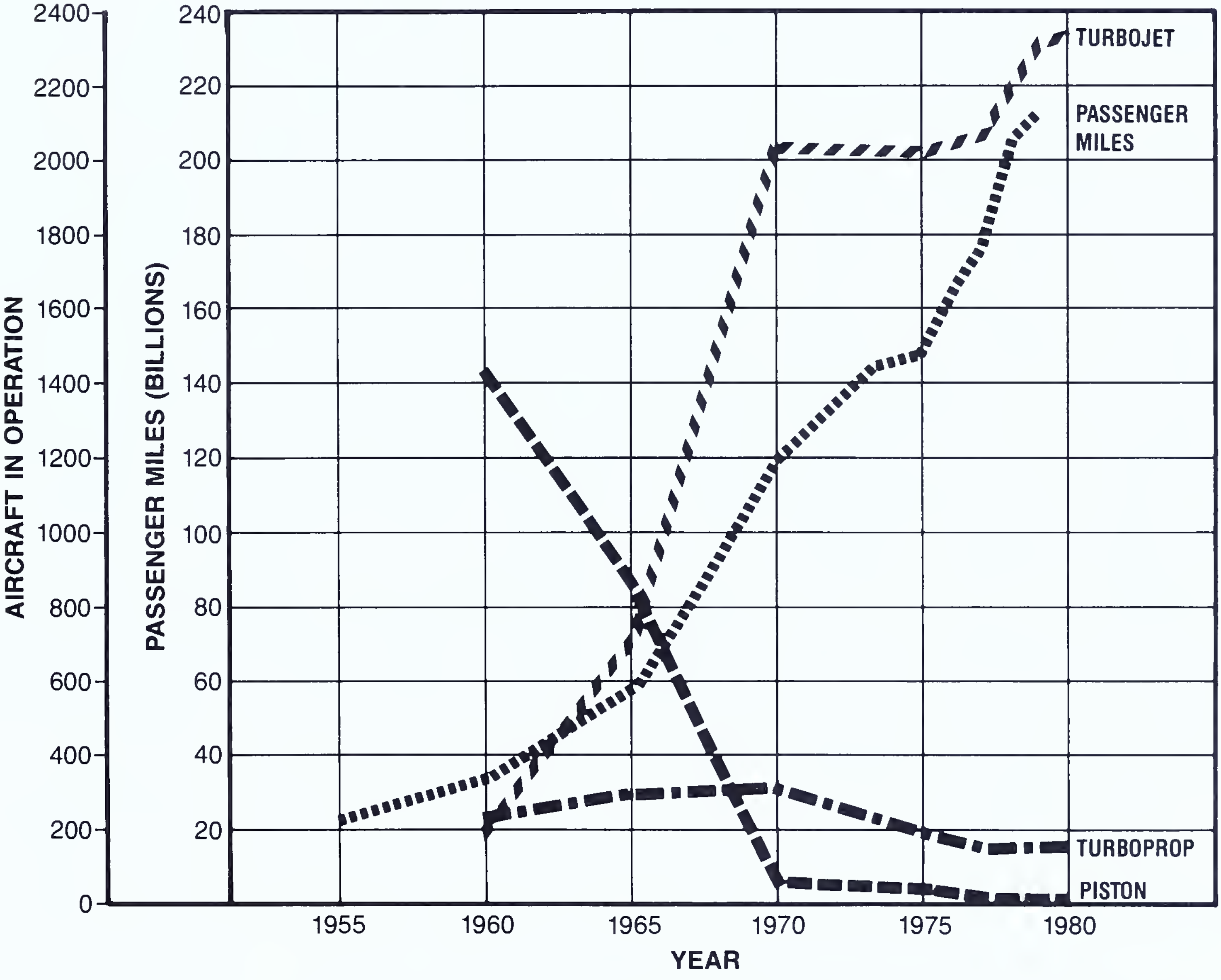
Annual Ridership in Thousands			
HSR System		Maglev System	
Low	High	Low	High
237	788	241	805

annually would use the high speed rail system. With the maglev alternative, the market increases to between 241,000 and 805,000 people annually.

- Projections (2000-2010). Precise forecasts with full certainty of either the future state of economic conditions or of human behavior when presented with a new transportation choice are not possible; therefore a range of market demand estimates was prepared. In addition, it was determined that due to changes in the preferences of travel on new modes, some increase in travel should be observed as the operational reliability and safety of the new system are proven. Although this characteristic of the change in perception of travel has been observed in France, it has also been observed in the United States. Air travel statistics, shown in Figure 48, illustrate a fairly significant increase in the number of passenger miles of travel as the

FIGURE 48

AIR TRAVEL STATISTICS



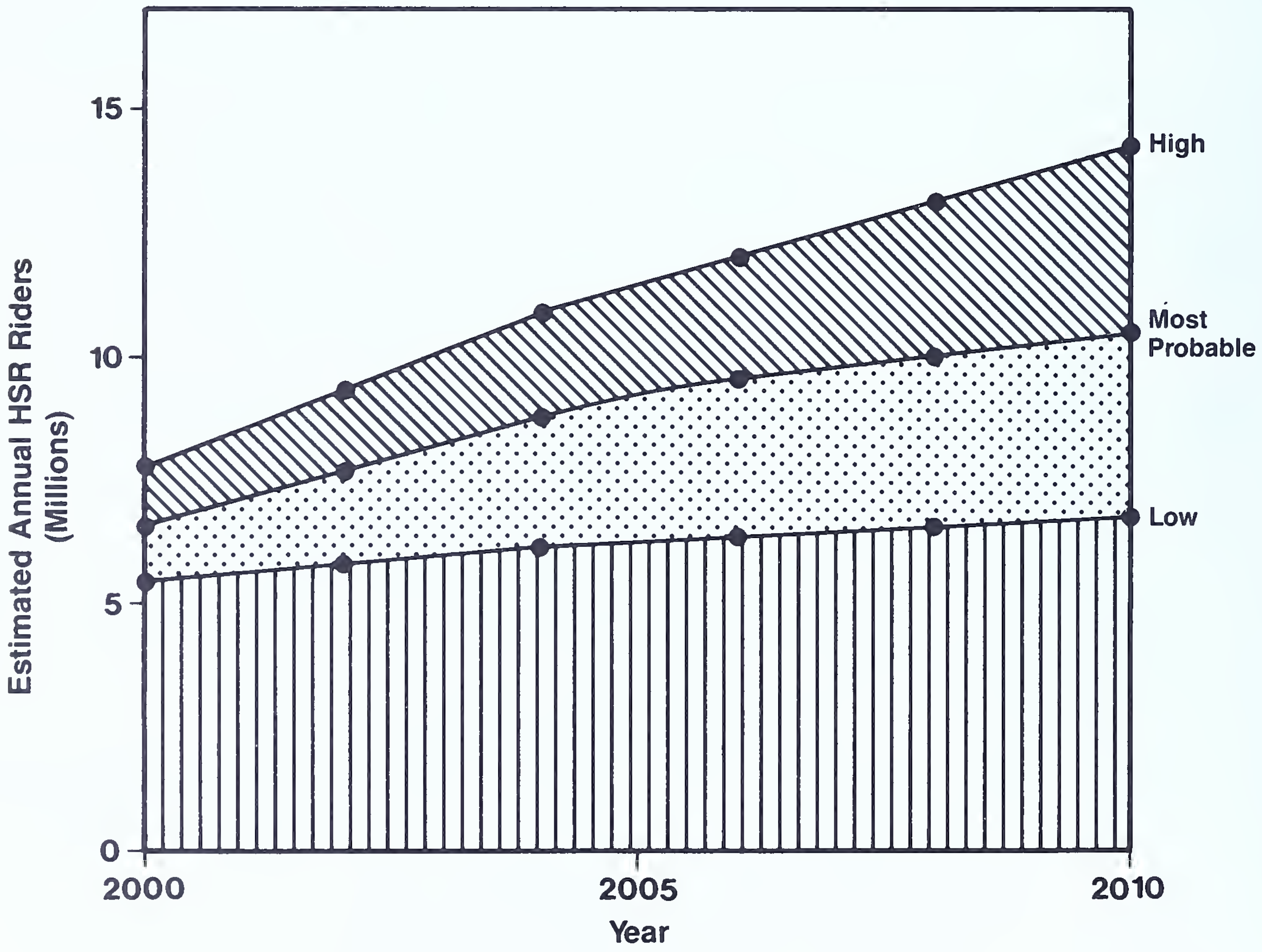
SOURCE: Statistical Abstract of the United States—1981.

number of turbojet aircraft increased from 1960 to 1980. The fairly significant reduction in travel time resulted in an increase in the number of passengers of approximately 10% per year for a period of 10 years. Although this type of increase has not been observed in the Northeast Corridor, it was assumed that an increase of between 3% and 9% per year was a reasonable estimate for the type of high speed rail service being contemplated.

The resultant estimate of high speed rail riders is shown in Figure 49. The "most probable" estimate is based on the projected socioeconomic conditions, which provides an estimate of approximately 6.2 million rail riders per year. In addition, it was assumed that approximately 84,000 additional riders annually would use this high speed rail system to connect with Amtrak's Atlantic City service and approximately 237,000 to a mid-state development. The "low" estimate is based on the assumption of "no growth" in population and employment and therefore only 5.4 million riders would use the high speed rail system. It was

FIGURE 49

ESTIMATES OF HSR RIDERSHIP



assumed, however, that 84,000 additional riders annually would use high speed rail service to make connections for trips to Atlantic City. The "high" estimate was developed by assuming that the estimated population and employment growth projected for the year 2000 would be achieved, and that approximately 10% more high speed rail riders would use the system, for a total of 6,872,800 riders. In addition, it was assumed that approximately 120,000 passengers would use high speed service to connect with the Atlantic City service and 788,000 riders would use the high speed rail system for trips to a mid-state development.

The "low" estimate is also based on a growth of approximately 3% per year for the first 4 years and 1½% per year for the next 6 years. For the "most probable" estimate, it was assumed that a growth rate of 6% per year would be achieved for the first 4 years and 3% per year for the next 6 years. The "high" estimate is based on the assumption of a growth in travel of 9% per year for the first 4 years and 4½% per year thereafter.

The total projections for the maglev system are provided in Figure 50. The same assumptions were used in developing the range of ridership that were used in developing the high speed rail forecasts. As indicated in this figure, it was assumed that the range in ridership would be between 6.25 million and 8.8 million during the year 2000. This ridership is expected to grow to between 7.7 million and 16.2 million by the year 2010. The "most probable" estimate would start at about 7.5 million in the year 2000 and increase to approximately 11.3 million by the year 2010.

The projections indicate that implementation of a high speed rail system could influence significantly travel in the Pennsylvania Corridor. Since the travel time from Philadelphia to Pittsburgh would be cut to nearly the same time that it now takes to travel between Harrisburg and Philadelphia, travel throughout the whole corridor should be enhanced. In addition, trips to both Philadelphia and Pittsburgh, as well as some shorter trips, should be induced by the implementation of either of the high speed rail systems being contemplated. The estimated volume of daily station-to-station rail trips is illustrated in the desire line diagram in Figure 51.

As shown in the figure, the number of daily high speed rail trips between Philadelphia and Pittsburgh is expected to be nearly 1,500, with about half as many trips between Harrisburg and these two major cities. Relatively strong travel attraction between Pittsburgh and Great Valley/Paoli also can be observed from analysis of the information in the figure.

The results of this analysis of travel desire, due to the implementation of a high speed rail service, are consistent with observations obtained from the analysis of rapid rail systems throughout the country; that is, people are willing to travel farther to work, for business purposes, and for recreation as long as the travel time is within their self-imposed constraints. The implementation of the Philadelphia to Lindenwold, New Jersey, rapid rail system is an excellent example of this phenomena where people moved farther away but essentially stayed within the same total travel time. The same experience has been observed in Washington, D.C., San Francisco, and Atlanta where new rapid rail systems have recently been implemented.

FIGURE 50
ESTIMATES OF MAGLEV RIDERSHIP

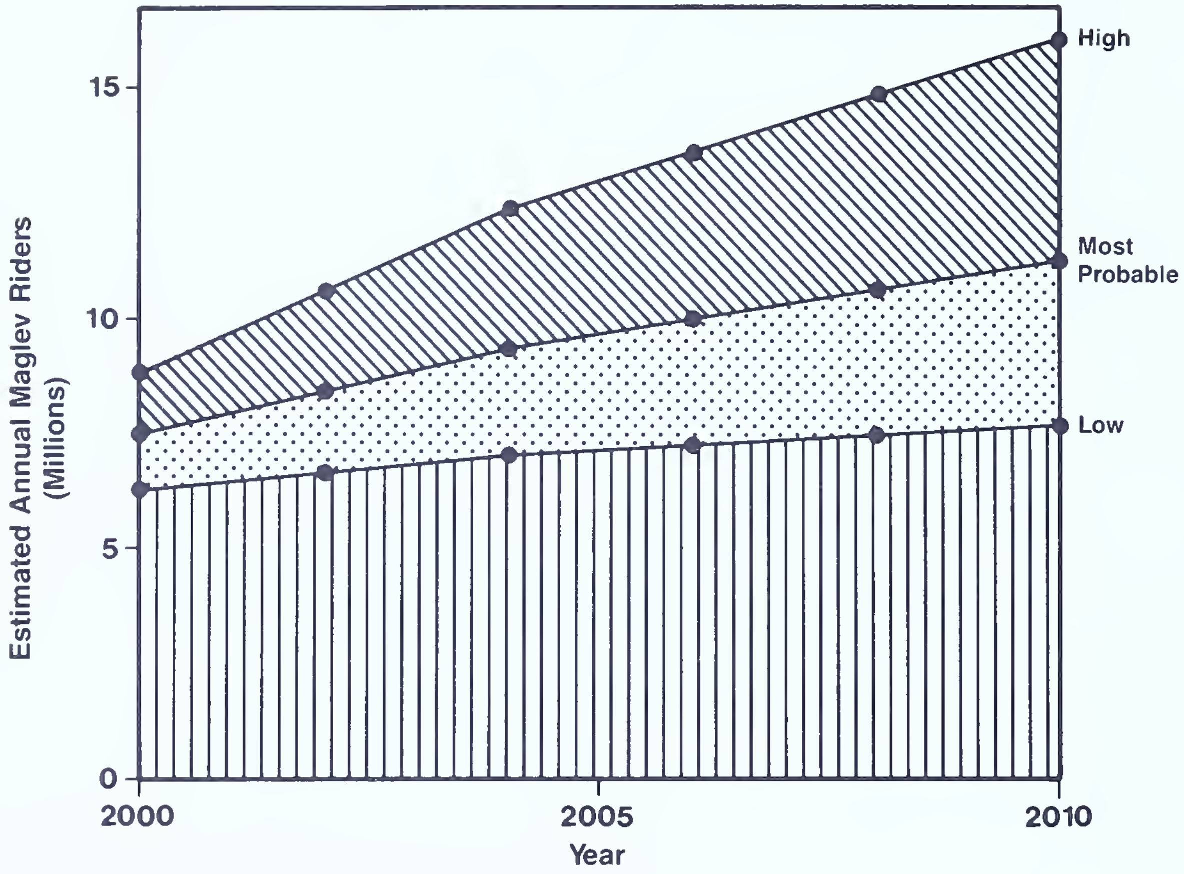
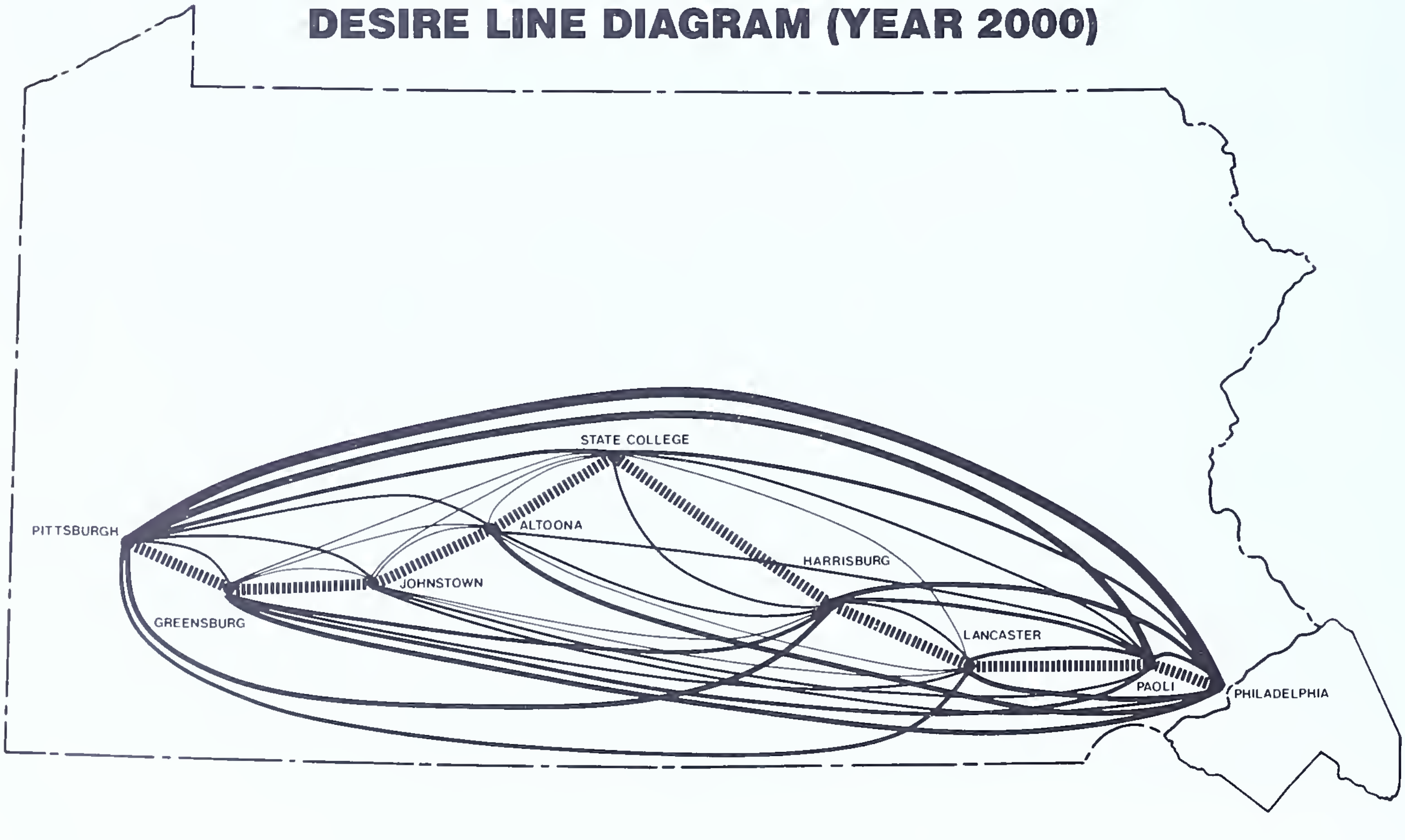


FIGURE 51
DAILY STATION-TO-STATION RAIL TRIPS DESIRE LINE DIAGRAM (YEAR 2000)



TESTS OF REASONABLENESS

Although the projected high speed rail market demand is considered to be reasonably conservative, there are still many uncertainties associated with these projections. Some of these uncertainties and major assumptions are discussed in the following sections to more fully explain the reasonableness of the projections.

- Competing Transportation Services. The other transportation services competing for intercity travel in the Pennsylvania High Speed Rail Corridor are the airlines, bus systems, and highways (automobile). In the year 2000, the expected shift to high speed rail from the competing services is illustrated in Table 15.

TABLE 15

Expected Shift in Daily Ridership to High Speed Rail

Competing Service	Base Case (Existing Rail Service)		Year 2000			
			High Speed Rail		Maglev	
	1985	2000	Ridership	Shift to HSR	Ridership	Shift to Maglev
Airlines	2,761	2,980	2,670	310	2,660	320
Bus	4,970	5,080	5,000	80	4,990	90
Highway (Auto)	1,415,937	1,542,710	1,532,730	9,980	1,531,780	10,930

The largest number of high speed rail travelers is expected to come from highway users, but this represents only about 1% of the total daily highway intercity trip volume. Also, it can be observed that highway travel is still expected to increase by more than 115,000 daily trips over the 1985 observations, even if a maglev system is built. The highest percentage of people shifting modes is from the airlines where between 10% and 11% are expected to shift to high speed rail. The number of bus riders changing to high speed rail is relatively small; it is less than 2% of the projected bus ridership. Most of these changes are expected to come from the longer distance bus trips. Also, the number of bus trips in the year 2000 still is expected to be slightly greater than the 1985 observations, even if a maglev system is built.

- Development. As with the implementation of jet air travel, turnpikes, and interstate highways in the 1960's, it is anticipated that major real estate developments will emerge in the vicinity of high speed rail stations. At least part of the increase in airline travel from 1960 to 1970 can be attributed to the large developments occurring near major airports. Another reason for this increase in air travel is assumed to be a change in the perception of air travel; that is, as speed increased, schedule reliability improved, and safety became evident, more people shifted to air travel as a safe and reliable way to make longer-distance trips.

As previously explained, airline travel increased at an average annual rate of 10% per year from 1960 to 1970 as higher speed jet aircraft were introduced. Since it cannot be ascertained how much of this increase was due to development in the vicinity of the airports and how much to the change in perception of air travel and other factors, the possible impact of these factors has been evaluated parametrically in this study. For the high demand scenario, it was assumed that the growth rate could be as high as 9% for 4 years and then 4½% for the next 6 years. The low demand estimate assumes a growth rate of 3% per year for 4 years and then 1½% for the next 6 years; this relatively conservative estimate is similar to Amtrak's experience with Northeast Corridor service. The most probable estimate includes a growth rate of 6% per year for 4 years and then 3% per year for the next 6 years.

In summary, growth in market demand, due to development in the vicinity of high speed rail stations, has been considered in this analysis. However, this growth in rail travel is only partly due to development; future refinements in this growth resulting from the economic impact studies will provide more insight into the specific influence of development on high speed rail market demand.

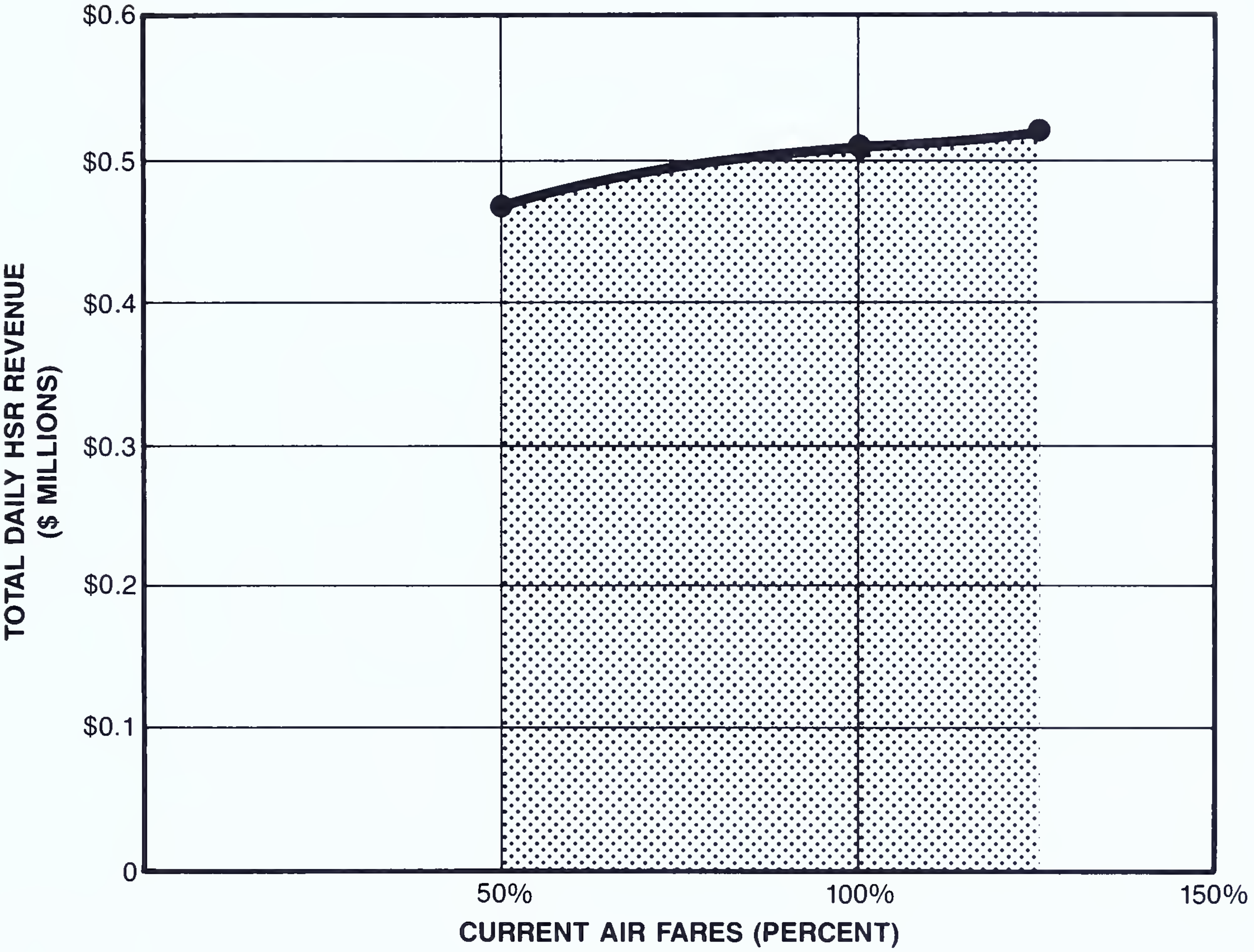
o Competitive Action. The introduction of a high speed rail system in Pennsylvania would undoubtedly result in some reductions in the fares of competing modes, which would benefit all passengers traveling in the corridor.

Since bus travel probably would not be affected appreciably, most of the competitive action would be expected from airlines. Therefore, it was assumed that airlines might reduce fares by as much as 50%, and this impact on predicted high speed rail travel is of interest. Another option is for airlines to improve service, cater primarily to the business traveler, and even increase airfares by 25%. This option would reduce air travel but could still bring an increase in airline revenues. Therefore, a range of options was evaluated to determine the overall effect of various airline strategies on high speed rail market demand. The results of this analysis are illustrated in Figure 52.

If the airlines reduce fares by approximately 50%, high speed rail ridership would be reduced by approximately 1,000 passengers daily and the average rail trip length would drop from 177 miles to 172 miles. This would result in a reduction of total daily high speed rail revenue of about 8% from nearly $508,000 per day to about $465,000 per day. However, if airlines increase fares by approximately 25%, the number of high speed rail passengers would rise by between 100 and 200 daily and high speed rail revenue would be increased by approximately 2%. Although the airlines might be able to cut fares by as much as 50%, it is not believed that they would be able to maintain this lower fare for long periods of time due to the probable increase in the price of gasoline and other airline operating costs.

FIGURE 52

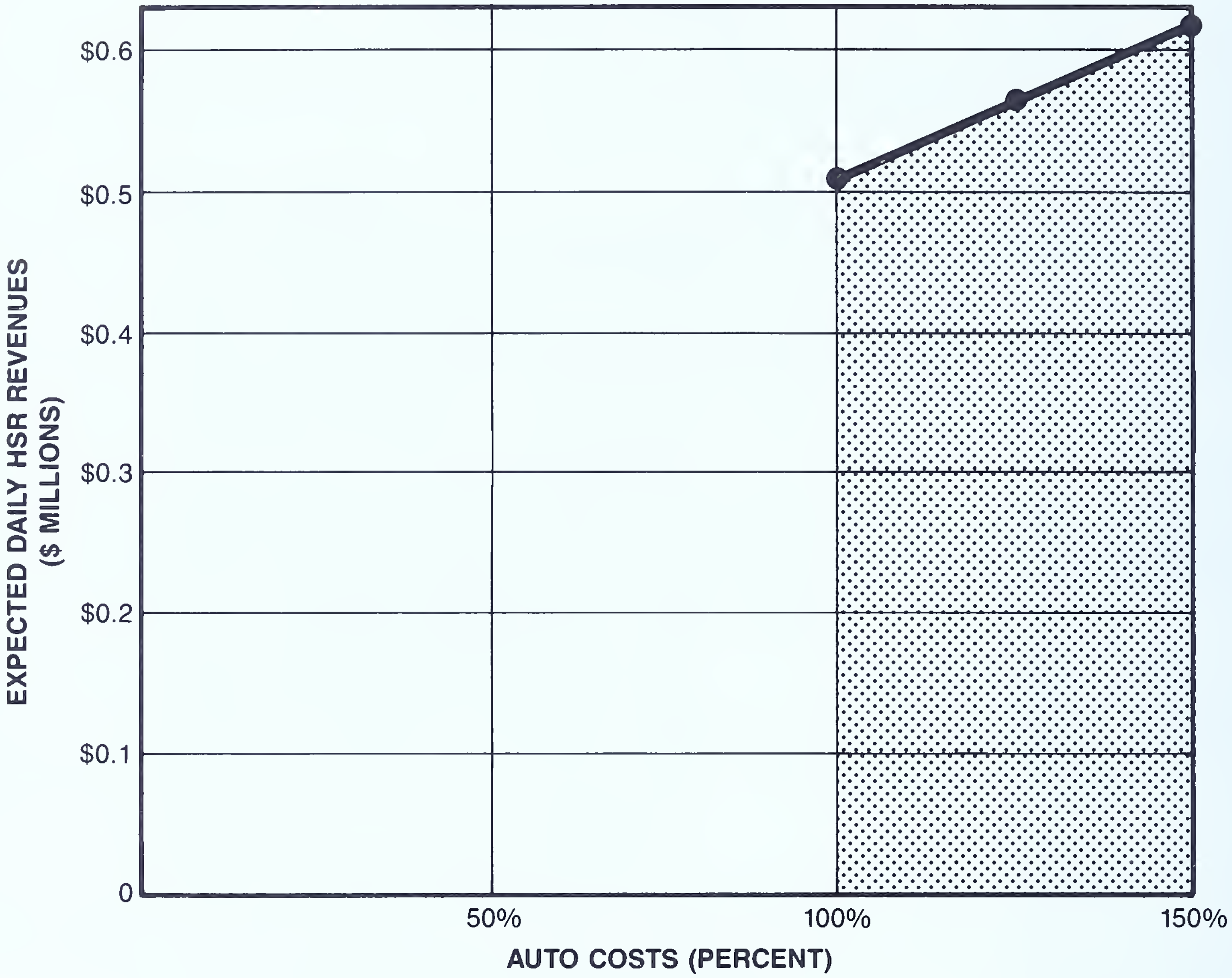
EVALUATION OF IMPACT OF VARIATIONS IN AIR FARE ON EXPECTED DAILY HSR REVENUES



Another possibility that could affect high speed rail revenues is the likely increase in automobile costs, especially due to the currently depressed price of gasoline. It was assumed in this study that automobile costs would remain at about 12¢ per mile but the price of gasoline has been increasing since those estimates were developed. Therefore, it is possible that the price of gasoline and automobile costs could increase by between 25% and 50% by the year 2000. If automobile costs rise by approximately 25%, rail ridership would increase by between 1,500 and 1,600 riders per day and the total daily revenues would be increased by about 11%, as illustrated in Figure 53. If gasoline and automobile costs increased by about 50% by the year 2000, rail ridership would rise by between 3,200 and 3,500 riders per day, and rail revenues would increase by approximately 22%. From this analysis, it is apparent that automobile costs, and especially increases in gasoline prices, could have a greater impact upon high

FIGURE 53

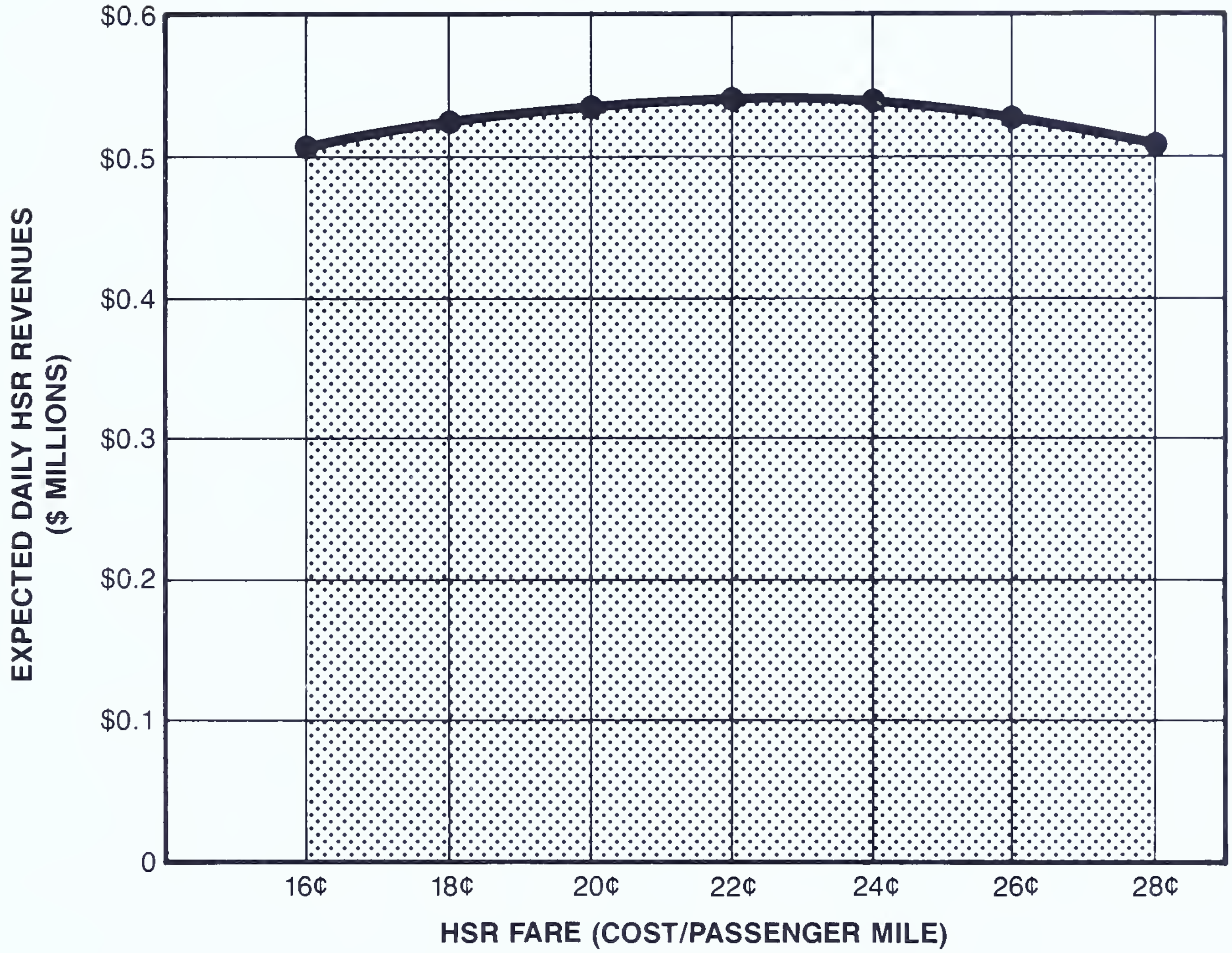
EVALUATION OF IMPACT OF INCREASES IN AUTO COSTS ON EXPECTED HSR REVENUES



speed rail ridership and total daily revenues than the reduction in airline fares. Since it is doubtful that the airlines could maintain a 50% reduction in airline fares for long periods of time, it is concluded that the expected total daily revenues on either of the two high speed rail options may be somewhat conservative.

Another option to optimize total daily high speed rail revenues is to conduct a detailed evaluation of high speed rail fares. The expected impact of increased high speed rail fares on high speed rail revenues is illustrated in Figure 54. This study assumed an average fare of 16¢ per passenger-mile resulting in a total revenue of approximately $508,000 per day. This analysis indicates that increasing rail fares from 16¢ per passenger-mile to 28¢ per passenger-mile would result in a reduction of the number of high speed rail passengers from about 17,920 to 11,590 daily. However, high speed rail revenues still would be

FIGURE 54
EXPECTED IMPACT OF INCREASE IN HSR FARES ON HSR REVENUES



increased even if fares were increased, as shown in Figure 54. From this analysis, an average high speed rail fare of about 22¢ per passenger-mile would result in a reduction in the number of high speed rail passengers from 17,920 to about 14,440 daily, but total daily revenues would rise by approximately 5%. Increasing high speed rail fares to optimize total daily revenues would have its greatest impact upon shifts from airlines to the high speed rail system since the average trip length would be reduced from 177 miles to about 168 miles. Therefore, an increase in airline travel probably would result in greater congestion at airports. Therefore, it was assumed that this type of higher fare might not foster the desired public support for high speed rail that a lower fare would, due to the expected change in impact on airports and airport congestion.

From the preceding analysis, it can be assumed that several competitive strategies could be used by both the high speed rail system and the other modes to optimize their total daily revenues. It is apparent that a more detailed evaluation should be conducted to establish the impact that these competitive actions would have on each high speed rail market. The goal of this evaluation would be to obtain the maximum total daily revenues while still providing the desired impact on highway and airport travel and congestion.

- Highway Construction. The preceding analysis indicates that a high speed rail system would not significantly reduce the requirement to maintain major highways within the high speed rail corridor. Since highway travel is still expected to increase from about 1.4 million intercounty trips per day to 1.5 million trips per day in the year 2000, even with a maglev high speed rail system, the planned additional highway construction still would be required.

  In developing the initial high speed rail market demand, it was assumed that levels of highway service would be maintained throughout the planning period and that additional highways would be constructed. However, it can be assumed that if this highway construction were not authorized and implemented, some additional high speed travel would result. However, this reduction in highway construction was not considered in the initial analysis and, therefore, the estimated daily ridership on the two high speed rail options may be somewhat conservative.

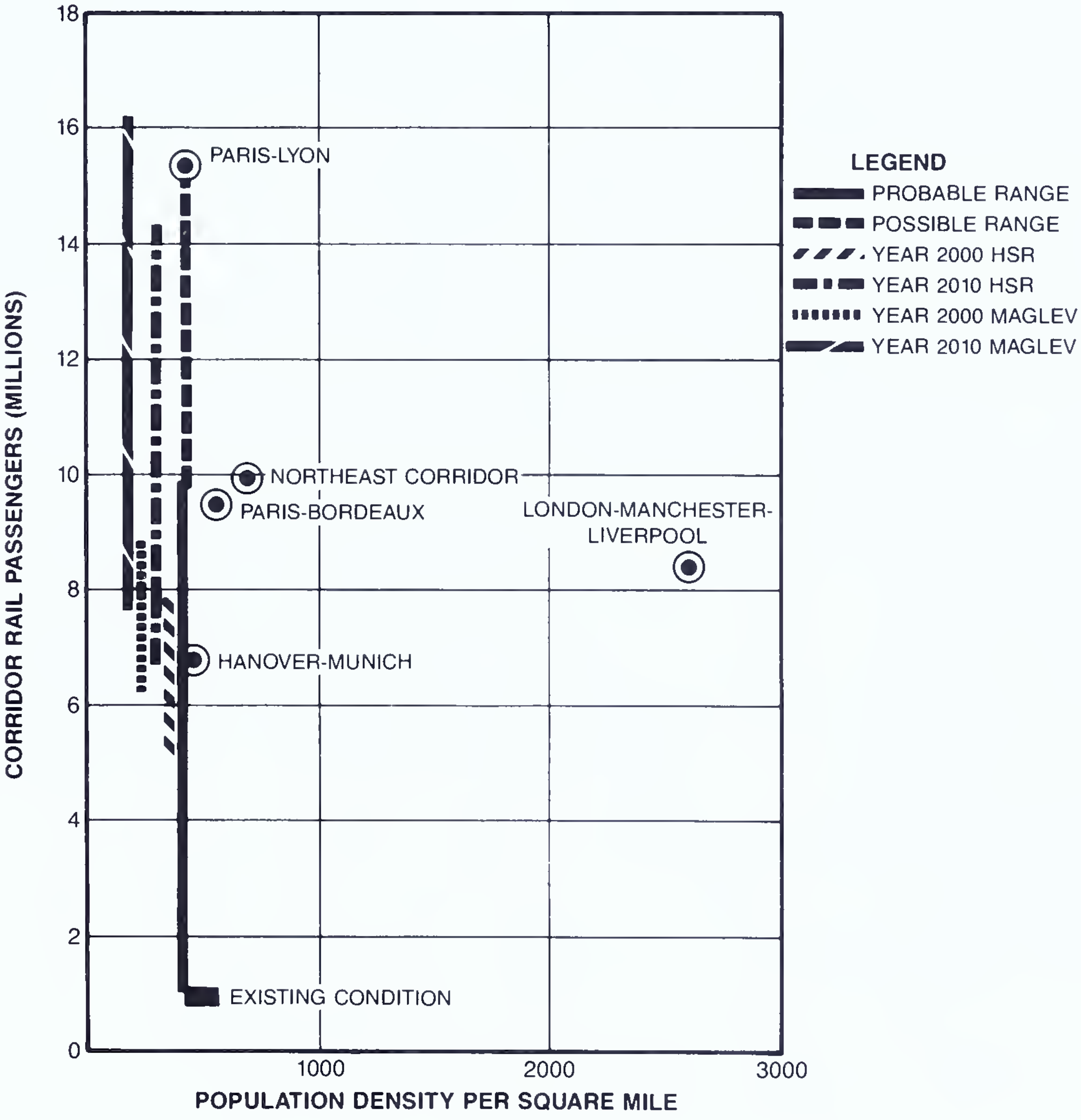
- Access and Egress. Although it is apparent that some improvements will be needed to reduce access and egress time at rail stations, it was assumed that these travel times would remain constant throughout the study period. However, requirements for automobile, bus, and other modal interface were considered in the development and design of the rail stations. These improvements are obviously essential to ensure that access and egress to the rail station is at least as convenient as it is at present. Of special importance is the inclusion of adequate parking in the station designs.

- Economic Activity. The present market demand analysis is not dependent on unusual activity such as additional tourism or gambling which are vulnerable to changes in economic conditions, fashions, and legal considerations. However, the tourist market and special gambling trips to Atlantic City were considered in the range of options and are part of the uncertainty in the forecast, as previously explained.

- Comparability. In order to provide as much authenticity as possible to the high speed rail forecast, a comparison of these forecasts to situations existing in other locations was conducted. This comparison of expected market demand is provided in Figure 55.

  Some of the major characteristics of high speed rail services throughout the world were evaluated, including population density, maximum speeds, corridor lengths, frequency of service, and ridership. From this analysis, a simple linear regression equation was developed to provide estimates of the "probable range" and "possible range" of high speed rail passengers within the high speed rail corridor. This analysis indicates that the probable range is from the existing condition of 1.0 million riders per year to about 9.8 million riders per year and the possible range could be high as 15.6 million riders per year. The analysis also indicates that the year 2000 estimates are between 5.4 million and 7.8 million for high speed rail, and are comparable to those currently achieved in the Hanover-Munich corridor and approximately 50% of those being achieved for the TGV high speed rail system in the Paris-to-Lyon Corridor. The year 2000 estimates for the maglev system range from 6.2 million to 8.8 million and these estimates are also well within the probable range. This volume is also approximately 50% of those presently being achieved on the Paris-Lyon high speed rail system. Even the projected year 2010 estimates are within the possible range with the exception of the year 2010 maglev high estimate of 16.2 million. The year 2010 high speed rail estimates vary from 6.7 million to 14.3 million and the maglev estimates range from 7.7 million to 16.2 million. All of these estimates appear to be well within a reasonable value and even the high estimates are not considered unattainable.

FIGURE 55
COMPARISON OF EXPECTED PENNSYLVANIA MARKET DEMAND WITH EXISTING HSR RIDERSHIP WORLDWIDE



APPENDIX A

SURVEY FORMS

During the conduct of the Market Demand Study, survey forms were distributed as follows:

	Rail	Turnpike	Air
Number of Forms Distributed	3,631	19,925	1,982
Number of Forms Returned	2,510	5,173	1,170
Response Rate	69.1%	26.0%	59.0%

Copies of the survey forms are attached.

R

Philadelphia - Pittsburgh Corridor
Rail Survey

The Pennsylvania High Speed Intercity Rail Passenger Commission is undertaking a CONFIDENTIAL study of travel within the Philadelphia - Harrisburg - Pittsburgh corridor. Your answers will be held in STRICTEST confidence and are extremely important in determining the travel behavior of rail passengers. The results of this study will enable the Commission to decide on a high speed rail system that will best serve the corridor. Please return this completed questionnaire to the representative on the train; if not possible, place it in the nearest mailbox as soon as possible.

If you already received and returned or mailed a questionnaire today, please check the box below and simply return this questionnaire, uncompleted, to our representative. Thank you for your cooperation.

☐

PLEASE CHECK THE APPROPRIATE BOX OR FILL IN THE BLANK

Trip Characteristics

1. Where did you start this trip?

☐ Home
☐ Place of work
☐ School
☐ Location of business visit
☐ Vacation location
☐ Shopping, social or other personal business location
☐ Convention or conference

2. Where will this trip end?

☐ Home
☐ Place of work
☐ School
☐ Location of business visit
☐ Vacation location
☐ Shopping, social or other personal business location
☐ Convention or conference

3. How often do you make this trip?

☐ Three or more times per week ☐ One or two times per week ☐ At least once a month ☐ Occasionally

4. Where did you get on this train?

Station Name ____________________

5. From what location did you travel to the above station?

City, Borough, Village or Township ____________________________

County, State (and Zip Code, if known) ____________________________

6. How did you get to the station to get on this train?

☐ Bus
☐ Walk
☐ Auto drive and park
☐ Auto ride
☐ Taxi or limousine
☐ Train
☐ Other _______________

7. About how far did you travel to reach the station?

________ miles ________ minutes

8. About how much time did you spend in the station before the departure of the train?

________ minutes

9. Where will you get off this train?

Station Name ____________________

10. What is the destination of this trip?

City, Borough, Village or Township ____________________________

County, State (and Zip Code, if known) ____________________________

11. How will you get to the above location from the station?

☐ Bus
☐ Walk
☐ Auto ride
☐ Taxi or limousine
☐ Train
☐ Other ___________________

12. About how far will you travel to reach your destination after you leave this train?

________ miles ________ minutes

13. How many are traveling with you as a group (friends, colleagues, family members, etc.)? (Do not include yourself.)

☐ None ☐ One ☐ Two ☐ Three ☐ More than three

14. How much did you pay for this train trip?

$ ____________

☐ One-way
☐ Round trip
☐ Monthly
☐ Weekly
☐ Full Fare
☐ Excursion Fare
☐ All Aboard America Fare
☐ Commuter Fare
☐ Employee Pass

(Please Continue on Reverse)

15. Who is paying for this trip?

☐ Yourself ☐ Company/Other

Background Information

16. Which of the following best describes your occupation? (Check ONE)

☐ Agriculture, forestry, fisheries
☐ Transportation, communication, and other public utilities
☐ Wholesale and retail trade
☐ Service industries (business, personal entertainment, professional, and related services)
☐ Mining
☐ Construction
☐ Manufacturing
☐ Finance, insurance, and real estate
☐ Government, public administration
☐ Retired
☐ Unemployed
☐ Student
☐ Homemaker

17. Where is your home located?

City, Borough, Village or Township ______________________________

County, State and Zip Code ______________________________

18. What is your family income before taxes in the last year?

☐ under $10,000
☐ $10,000-$14,999
☐ $15,000-$19,999
☐ $20,000-$24,999
☐ $25,000-$49,999
☐ $50,000 and over

19. How many cars are operated by your family?

☐ None ☐ One ☐ Two ☐ Three ☐ More than three

20. What is your sex?

☐ Female ☐ Male

21. What is your age group?

☐ 17 and under
☐ 18-24
☐ 25-34
☐ 35-44
☐ 45-64
☐ 65 and over

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A

Philadelphia - Pittsburgh Corridor
Intercity Travel Improvements
Air Travel Survey

The Pennsylvania High Speed Intercity Rail Passenger Commission is undertaking a CONFIDENTIAL study to improve intercity travel in the Philadelphia - Harrisburg - Pittsburgh corridor. Your answers will be held in STRICTEST confidence and are extremely important in determining the travel behavior of air travelers. The results of this study will enable the commission to make recommendations for corridor travel improvements.

Please return this completed questionnaire by dropping it in the box, handing it to the surveyor at the exit gate or by placing it in the nearest mailbox as soon as possible.

If you have already received and returned or mailed a questionnaire today, please check the box below and return this questionnaire uncompleted. Thank you for your cooperation.

☐

PLEASE CHECK THE APPROPRIATE BOX OR FILL IN THE BLANK

Trip Characteristics

1. Where did you start this trip?

☐ Home
☐ Place of work
☐ School
☐ Location of business visit
☐ Vacation location
☐ Shopping, social or other personal business location
☐ Convention or conference

2. Where will this trip end?

☐ Home
☐ Place of work
☐ School
☐ Location of business visit
☐ Vacation location
☐ Shopping, social or other personal business location
☐ Convention or conference

3. How often do you make this trip?

☐ Three or more times per week ☐ One or two times per week ☐ At least once a month ☐ Occasionally

4. Did you transfer to this plane from another plane?

☐ Yes ☐ No

If yes, go to question no. 8.

5. From what location did you travel to board this plane?

City, Borough, Village or Township ______________________

County, State (and Zip Code, if known) ______________________

6. How did you get to the airport to board this plane?

☐ Auto drive and park
☐ Auto ride (including courtesy van)
☐ Rental car (including drop off by car rental agency)
☐ Taxi or limousine
☐ Bus
☐ Other ____________

7. About how far did you travel to reach the airport?

________ miles ________ minutes

8. About how much time did you spend in the airport before boarding the plane?

________ minutes

9. What is the destination of this trip?

City, Borough, Village or Township ______________________

County, State (and Zip Code, if known) ______________________

10. How will you get to the above location?

☐ Another airplane/airline
☐ Drive auto parked at the airport
☐ Auto ride (including courtesy van)
☐ Rental car (including pick up by car rental agency)
☐ Taxi or limousine
☐ Bus
☐ Other ____________

11. About how far will you travel to reach your destination from the airport?

________ miles ________ minutes

12. How many are traveling with you as a group (friends, colleagues, family members, etc.)? (Do not include yourself.)

☐ None ☐ One ☐ Two ☐ Three ☐ More than three

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13. How much did you pay for this plane trip?

Regular fare one-way ticket $________ round-trip ticket $________
Discount fare one-way ticket $________ round-trip ticket $________

14. Who is paying for this trip?

☐ Yourself ☐ Company/Other

Background Information

15. Which of the following best describes your occupation? (Check ONE)

- ☐ Agriculture, forestry, fisheries
- ☐ Transportation, communication, and other public utilities
- ☐ Wholesale and retail trade
- ☐ Service industries (business, personal entertainment, professional, and related services)
- ☐ Mining
- ☐ Construction
- ☐ Manufacturing
- ☐ Finance, insurance, and real estate
- ☐ Government, public administration
- ☐ Retired
- ☐ Unemployed
- ☐ Student
- ☐ Homemaker

16. Where is your home located?

City, Borough, Village or Township ______________________________

County, State and Zip Code ______________________________

17. What is your family income before taxes in the last year?

☐ under $10,000 ☐ $15,000-$19,999 ☐ $25,000-$49,999
☐ $10,000-$14,999 ☐ $20,000-$24,999 ☐ $50,000 and over

18. How many cars are operated by your family?

☐ None ☐ One ☐ Two ☐ Three ☐ More than three

19. What is your sex?

☐ Female ☐ Male

20. What is your age group?

☐ 17 and under ☐ 25-34 ☐ 45-64
☐ 18-24 ☐ 35-44 ☐ 65 and over

T

Philadelphia - Pittsburgh Corridor
Turnpike Survey

The Pennsylvania High Speed Intercity Rail Passenger Commission is undertaking a CONFIDENTIAL study of travel in the Philadelphia - Harrisburg - Pittsburgh corridor. Your answers will be held in STRICTEST confidence and are extremely important in the determination of the travel behavior of turnpike users. The results of this study will enable the Commission to decide on a high speed rail system that will best serve the corridor.

Either the driver or a passenger may fill out the form. If you are traveling alone and will not be able to complete the form by the time you exit the turnpike, please keep the form and fill it out when you reach your destination. Please return this questionnaire by placing it in the nearest mailbox as soon as possible.

If you have already received and returned or mailed a questionnaire today, please check the box below and return this questionnaire uncompleted.

☐

Thank you for your interest and cooperation.

PLEASE CHECK THE APPROPRIATE BOX OR FILL IN THE BLANK

Trip Characteristics

1. Where did you start this trip?

☐ Home
☐ Place of work
☐ School
☐ Location of business visit
☐ Vacation location
☐ Shopping, social or other personal business location
☐ Convention or conference

2. Where will this trip end?

☐ Home
☐ Place of work
☐ School
☐ Location of business visit
☐ Vacation location
☐ Shopping, social or other personal business location
☐ Convention or conference

3. How often do you make this trip?

☐ Three or more times per week ☐ One or two times per week ☐ At least once a month ☐ Occasionally

4. From what location did you travel to the turnpike entrance you used?

City, Borough, Village or Township ______________________

County, State (and Zip Code, if known) ______________________

5. About how far did you travel to reach the PA turnpike entrance?

________ miles ________ minutes ________ Entrance No.

6. Which exit will/did you use to leave the PA Turnpike?

Exit No. ________

7. What is the destination of this trip?

City, Borough, Village or Township ______________________

County, State (and Zip Code, if known) ______________________

8. About how far from the PA Turnpike exit is your final destination?

________ miles ________ minutes

9. How many are traveling with you as a group (friends, colleagues, family members, etc.)? (Do not include yourself.)

☐ None ☐ One ☐ Two ☐ Three ☐ More than three

10. What is your estimate of costs for this trip (include tolls, parking and gasoline/fuel.)

____

11. Who is paying for this trip?

☐ Yourself ☐ Company/Other

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Background Information

12. Which of the following best describes your occupation? (Check ONE)

- ☐ Agriculture, forestry, fisheries
- ☐ Transportation, communication, and other public utilities
- ☐ Wholesale and retail trade
- ☐ Service industries (business, personal entertainment, professional, and related services)
- ☐ Mining
- ☐ Construction
- ☐ Manufacturing
- ☐ Finance, insurance, and real estate
- ☐ Government, public administration
- ☐ Retired
- ☐ Unemployed
- ☐ Student
- ☐ Homemaker

13. Where is your home located?

City, Borough, Village or Township ______________________

County, State and Zip Code ______________________

14. What is your family income before taxes in the last year?

☐ under $10,000 ☐ $10,000-$14,999 ☐ $15,000-$19,999 ☐ $20,000-$24,999 ☐ $25,000-$49,999 ☐ $50,000 and over

15. How many cars are operated by your family?

☐ None ☐ One ☐ Two ☐ Three ☐ More than three

16. What is your sex?

☐ Female ☐ Male

17. What is your age group?

☐ 17 and under ☐ 18-24 ☐ 25-34 ☐ 35-44 ☐ 45-64 ☐ 65 and over

Pennsylvania High Speed Intercity Rail Passenger Commission
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Harrisburg, PA 17120
(717) 787-8748

Submitted by:

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Contact: John Q. Hargrove